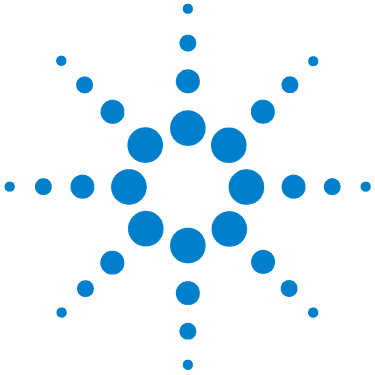

Agilent 85190A
IC-CAP 2008

Reference

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Notices

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Supported Instruments

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This chapter discusses the instruments supported by IC-CAP and describes the options for each instrument. The instruments are divided into basic groups:

- DC analyzers
- Capacitance-Voltage meters
- Network analyzers
- Oscilloscopes
- Pulse generators
- Dynamic signal analyzers

DC Analyzers

DC analyzers source and monitor voltages and currents and return data representing DC characteristics. IC-CAP supports the following DC analyzers:

- HP 4071A Semiconductor Parametric Tester
- HP 4140 pA Meter/DC Voltage Source
- HP 4141 DC Source/Monitor
- HP/Agilent 4142 Modular DC Source/Monitor
- HP 4145 Semiconductor Parameter Analyzer
- HP/Agilent 4155 Semiconductor Parameter Analyzer
- HP/Agilent 4156 Precision Semiconductor Parameter Analyzer
- Agilent E5260 Series Parametric Measurement Solutions
- Agilent E5270 Series Parametric Measurement Solutions
- Agilent B1500A Semiconductor Device Analyzer

CAUTION IC-CAP does not restrict bias magnitude. When using a DC analyzer as a bias source for other instruments such as capacitance-voltage meters or network analyzers, check the limit on external bias voltage or current for each instrument. Excessive voltage or current may damage other instruments.

HP 4071A Semiconductor Parametric Tester

The HP 4071A IC-CAP driver enables you to control the HP 4071A Semiconductor Parametric Tester from within IC-CAP.

NOTE

IC-CAP requires the Agilent 4070 System Software (also referred to as TIS), version B.02.00, or higher, to drive the Agilent 4071 Semiconductor Parametric Tester.

The Agilent 4071 Semiconductor Parametric Tester is only supported on the HP-UX 11i platform.

For assistance using the Agilent 4070 System Software (TIS), please contact your local Agilent Instrument Support Team.

GPIB Interface

The HP 4071A does not have a GPIB interface available by which you can control measurements. However, in keeping within the IC-CAP framework, an interface is required by the hardware manager in IC-CAP. The interface choices for the HP 4071 are limited to *tis_offline*, and *tis_online*. *tis_offline* runs the HP 4071 driver in a mode that does not require that the HP 4071 system be connected. *tis_online* runs the HP4071 driver in a mode that communicates with the HP 4071 system when one is available. You can add an interface in the Hardware Setup window using **Tools > Hardware Setup** in the IC-CAP/Main window, then click on **Rebuild** to set up the tester.

IC-CAP will invoke the hp4070 executable if it is not already running or is shutdown during an IC-CAP function. Therefore, in the window where you start IC-CAP, you must set the PATH environment variable to the directory where the hp4070 executable is located. The typical installation directory for the hp4070 executable is */opt/hp4070/bin*.

Pin Connections

The HP 4071A switch matrix is controlled by the values entered for each of the *Pins* options in the Instrument Options Table. You can view the instrument options in the Model window after setting up the HP 4071 hardware, and creating an input for a setup. Highlight the setup name, then click on the **Instrument Options** tab. The values for the *Pins* option describes which PORT is connected to the available test head pins. Generally, each SMU has the same options implemented in the driver. One exception is that the Guard Pins option available for SMU1 and SMU2 are not available for SMU3. See the available instrument options in Table 1.

The following table shows examples of valid entries for *Pins* and the resulting connections:

Valid Pins Field Entry	Resulting Pin Connections
10	10
1,5,7,9	1, 5, 7, 9
2,4-7,9	2, 4, 5, 6, 7, 9
2,4-7,9,0	Not connected
35,5,2-4	35, 5, 2, 3, 4
12-16	12, 13, 14, 15,16

Notice that valid entries include a series of numbers separated by commas, and a range of numbers using a dash. A *0* appearing anywhere in a *Pins* field disconnects the PORT from the switch matrix. This is an easy way to disconnect the PORT without having to erase the pin numbers. The *Pins* field also can be left blank.

If the *Pins* field is left blank, then ICCAP will search for a pre-defined IC-CAP variable. The string value of the pre-defined IC-CAP variable becomes the *Pins* entry for the corresponding PORT. You can view the pre-defined IC-CAP variables by clicking on the Model Variables tab in the Model window.

You may use these pre-defined IC-CAP variables in PEL programs and Macros, which enables you to programmatically change the pin assignments of each PORT. The following program listing is a PEL macro snippet that manipulates pin assignments. Though pin values for variables SMU1-4 are pre-defined, you can see that the variables are being assigned new values before an *iccap_func* statement is executed.

```
n = 1
while (n <= 17)
HP4070_SMU1 = n
HP4070_SMU2 = n + 1
HP4070_SMU3 = n + 2
HP4070_SMU4 = n + 3
print “SMU1=”, HP4070_SMU1
print “SMU2=”, HP4070_SMU2
print “SMU3=”, HP4070_SMU3
print “SMU4=”, HP4070_SMU4

iccap_func(“/Test1/SMU/sweepOrder1”, “measure”)
n = n + 4
end while
```

Prober Functions

The HP 4071A driver incorporates the TIS prober control functions as IC-CAP PEL functions. The TIS prober functions are described briefly in this section. The *tis_prober_init()* function is described in detail because its arguments differ slightly from the TIS function *prober_init()*. The remaining functions have the same arguments as their TIS counterparts. Consult the *TIS Function Reference* for complete descriptions of all prober commands. All prober functions return 0 when successful, and -1 when they fail.

tis_prober_init (*selectCode, busAddress, ProberType, InterfaceName*)

selectCode - Integer value, range 0 and 7-31. This is the GPIB select code. Setting *selectCode* and *busAddress* to 0 retrieves the GPIB select code and bus address from PCONFIG file.

busAddress - Integer value, range 0-30. This is the GPIB bus address. Setting *selectCode* and *busAddress* to 0 retrieves the GPIB select code and bus address from PCONFIG file.

ProberType - String value, 30 characters max. String that specifies the type of prober. See *TIS Function Reference* for prober types.

InterfaceName - String value. This is the interface name, either TIS_OFFLINE or TIS_ONLINE.

tis_p_home ()

Used for loading a wafer onto the chuck and moving it to the home position.

tis_p_up ()

Moves the chuck of the wafer prober up.

tis_p_down ()

Lowers the chuck of the wafer prober.

tis_p_scale (*xIndex, yIndex*)

Defines the X & Y stepping dimensions that are used by the tis_p_move and tis_p_imove functions.

tis_p_move (*xCoordinate, yCoordinate*)

Moves the chuck to an absolute position.

tis_p_imove (*xDisplacement, yDisplacement*)

Moves the chuck a relative increment from its current position.

tis_p_orig (*xCoordinate, yCoordinate*)

Defines the current X & Y position of the chuck. Must be called before calling the *tis_p_move* or *tis_p_imove* functions.

tis_p_pos (*xPosition, yPosition*)

Returns the current X & Y position of the chuck.

tis_p_ink (*inkCode*)

Calls the inker function of the prober if it is supported.

tis_prober_reset ()

Sends a device clear command to the prober.

tis_prober_status (*isRemote, onWafer, lastWafer*)

Sends a query to the prober to obtain the Remote/Local control state and the edge sensor contact state. The prober should be initialized with *tis_prober_init* before this function.

t**is_prober_get_name** (*proberModeName*)

Sends query to prober to read name of current mode.

tis_prober_get_ba (*proberBusAddress*)

Sends query to prober to read its bus address.

tis_prober_read_sysconfig (*proberType, scba*)

Sends query to prober to read its complete interface address including instrument type, select code, and bus address.

The following PEL macro example uses the prober functions. For the prober used in this example, notice that the operator *must* manually place the prober into AUTO PROBE mode while the program is actively querying the prober and it is in remote mode. Also notice that *isRemote*, *isOnWafer*, and *isLastWafer* must be parameters that appear in a variable list such as Model Variables.

```
status = -1
busAddress = 0
selectCode = 0
proberType = “EG4080X”
interfaceName = “TIS_ONLINE”
stepSizeX = 500
stepSizeY = 300
isRemote = 0
isOnWafer = 0
isLastWafer = 0
dum = 1

! Prober Commands return 0 for success, -1 for failure
dum = tis_prober_reset()
status=tis_prober_init(selectCode,busAddress,proberType,inte
rfaceName)
if (status == 0) then
status = tis_p_scale(stepSizeX, stepSizeY)
print “status =”, status
end if

if (status == 0) then
status = tis_prober_status(isRemote, isOnWafer, isLastWafer)
print “status =”, status
print “isRemote =”, isRemote
end if

if (status == 0) then
```

```
linput “Align the wafer. Press OK, then press [AUTO PROBE]”,
ans
! EG4080X MUST be actively querying bus when AUTO PROBE is
commenced
while (isRemote == 0)
dum2 = tis_prober_status (isRemote, isOnWafer, isLastWafer)
end while

print “isRemote =”, isRemote
if (isRemote ==1) then
status = 0
end if
end if

if (status == 0) then
dum = tis_p_orig(5.0,5.0)
n = 1
while (n < 5)
dum = tis_p_move(n,n)
n = n + 1
end while
end if
```

Instrument Options for the HP 4071A

The following table describes the HP 4071A options and their default values.

Table 1 HP 4071A Options

Option	Description
Use User Sweep	Yes = use user mode sweep. No = use system mode, when all required conditions are met. Default = No.
Hold Time	Time to allow for DC settling before starting internal or user sweep. Maximum 655 seconds. Default = 0.
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. Maximum 65 seconds. Default = 100 msec.
Fast ADC Integration Mode	Sets the integration mode for fast A/D converter to 0 = Manual, 1 = Short, 2 = Medium, 3 = Long. Default = 2.

Table 1 HP 4071A Options (continued)

Option	Description
Fast ADC Integration Value	Sets the integration time in Power Line Cycles (PLC) or number of samples to average for integration. Allowed values depend on setting for Fast ADC Integration Mode: If Integration Mode = 0 or 1, samples = 0, 1 to 4096. Default = 1. If Integration Mode = 2, values are ignored, time is fixed to 1 PLC. If Integration Mode = 3, time = 0, 1 to 100 PLC. Default = 16. If 0 is entered as the value, the default value is used.
Use Smart Fast ADC Integ Mode	Yes/No, default = No. Specifying Yes will use *Smart* mode integration for fast A/D converter for current measurements. *Fast ADC Integ Mode* and *Fast ADC Integ Value* will still be used for voltage measurements.
Smart Fast ADC Integ Value	Sets the integration time in Power Line Cycles (PLC) for integration on current measurements when *Use Smart Fast ADC Integ Mode* is Yes. Values can be 0, or 1 to 100 PLC. If 0 is entered as the value, the default of 16 PLC will be used.
Slow ADC Integration Mode	Sets the integration mode for high-resolution (slow) A/D converter to 0 = Manual, 1 = Short, 2 = Medium, 3 = Long. Default = 2.
Slow ADC Integration Value	Sets the integration time in Power Line Cycles (PLC) or number of samples to average for integration. Allowed values depend on setting for Slow ADC Integration Mode: If Integration Mode = 0, time = 0, 80E-6 to 20E-3 seconds, or 1 to 100 PLC. Default = 240E-6 If Integration Mode = 1, time = 0, 80E-6 to 20E-3 seconds. Default = 480E-6. If Integration Mode = 2, values are ignored, time is fixed to 1 PLC. If Integration Mode = 3, time = 0, 1 to 100 PLC. Default = 16. If 0 is entered as the value, the default value is used.
Slow ADC Auto Zero On	Sets SMU auto zero function to 0 = Off or 1= On. When turned on, the offset error is canceled at each measurement. Default = last valid value.

Table 1 HP 4071A Options (continued)

Option	Description
Use Smart Slow ADC Integ Mode	Yes/No, default = No. Specifying Yes will use *Smart* mode integration for high-resolution (slow) A/D converter for current measurements. *Slow ADC Integ Mode* and *Slow ADC Integ Value* will still be used for voltage measurements.
Smart Fast ADC Integ Value	Sets the integration time in Power Line Cycles (PLC) for integration on current measurements when *Use Smart Slow ADC Integ Mode* is Yes. Values can be 0, or 1 to 100 PLC. If 0 is entered as the value, the default of 16 PLC will be used.
Ground Open Guard Terminals	Connects guard terminals of unused measurement pins to circuit common. 0 = Disconnects terminals, any other value connects them. Default = 0.
Pins	Sets the PORT that is connected to the test head pins.
Guard Pins	Sets the pins to use for guard terminal. Available only for SMU1 and 2.
Fast/Slow ADC	Selects ADC. F = high speed (fast), S = high resolution (slow).
Port Filter On	Sets the SMU output filter mode, 0 = Off, 1 = On. Higher speed measurement is used when filter is off. Overshoot voltage or current is reduced when filter is on. Default = 0.
V Range (0.0 = Auto)	Sets the SMU voltage range. For MPSMU, allowed range is -100 to 100, with recommended range of 0, 2, 20, 40, 100. For HPSMU, allowed range is -200 to 200, with recommended range of 0, 2, 20, 40, 100, 200. Default = 0 (auto range).
I Range (0.0 = Auto)	Sets the SMU current range. For MPSMU, allowed range is -0.1 to 0.1, with recommended range of 0, 1E-9, 1E-8, 1E-7, 1E-6, 1E-5, 1E-4, 1E-3, 1E-2, 1E-1. For HPSMU, allowed range is -1 to 1, with recommended range of 0, 1E-9, 1E-8, 1E-7, 1E-6, 1E-5, 1E-4, 1E-3, 1E-2, 1E-1, 1. Default = 0 (auto range).

Table 1 HP 4071A Options (continued)

Option	Description
Power Compliance	Sets SMU power compliance in Watts. Allowed range for MPSMU is 0, 0.001 to 2. Allowed range for HPSMU is 0, 0.001 to 14.
Pulse Mode On	Sets pulse mode. NO = off, YES = on.
Pulse Base	Sets level of waveform's base for pulsed spot measurements. For MPSMU, allowed range is -0.1 to 0.1. For HPSMU, allowed range is -1 to 1. See Figure 1 for pulse waveform characteristics.
Pulse Width	Sets width of pulse for pulsed spot measurements. Allowed range is 0.0005 to 2.0000 seconds. Default = 0.005. See Figure 1 for pulse waveform characteristics.
Pulse Period	Sets period of pulse for pulsed spot measurements. Allowed range is 0, 0.0050 to 5.0000 seconds. Default = 0.2. See Figure 1 for pulse waveform characteristics.
Perform Cal?	TRUE = IC-CAP invokes calibration routine if a calibration is needed. FALSE = IC-CAP does not invoke calibration routine if a calibration is needed.
Cal Type	Sets the type of calibration routine to perform. Values are OPEN, SHORT, BOTH. BOTH invokes the OPEN and SHORT calibration routines.
High Pin	High voltage pin connection.
Low Pin	Low voltage pin connection.
Guard Pins	Guard pin connection.
Integ Time	Sets the CMU measurement's integration time. Allowed values are 1 = Short, 2 = Medium, 3 = Long.
Hold Time	Sets the sweep hold time for C-G-V measurement by the CMU. Allowed range is 0 to 650.000 seconds. Default = 0.
Delay Time	Sets the sweep delay time for C-G-V measurement by the CMU. Allowed range is 0 to 650.000 seconds. Default = 0.
Freq	Sets the CMU measurement frequency. Allowed values are 1E+3, 1E+4, 1E+5, 1E+6 Hz.

Table 1 HP 4071A Options (continued)

Option	Description
Signal Level	Sets the CMU measurement's test signal level. Allowed range is 0 to 2.0 volts (standard), and 0 to 20.0 volts (option 001). Default = last valid setting, or 0.03.
High Pins	High voltage pin connection.
Low Pins	Low voltage pin connection.
Auto Zero On	Sets auto zero mode for DVM. 0 = disable, 1 = enable. Default = last valid setting.
Integ Time	Sets integration time for DVM. Allowed range is 0, 0.5E-6 to 999999.9E-6 seconds; 1 to 10 PLC and 10 to 100 PLC. If set to 0, integration time is set to default value. Default = 0.5E-6.

The following figure is a diagram of the pulse waveform used in pulsed spot measurements showing Pulse Base, Width, and Period.

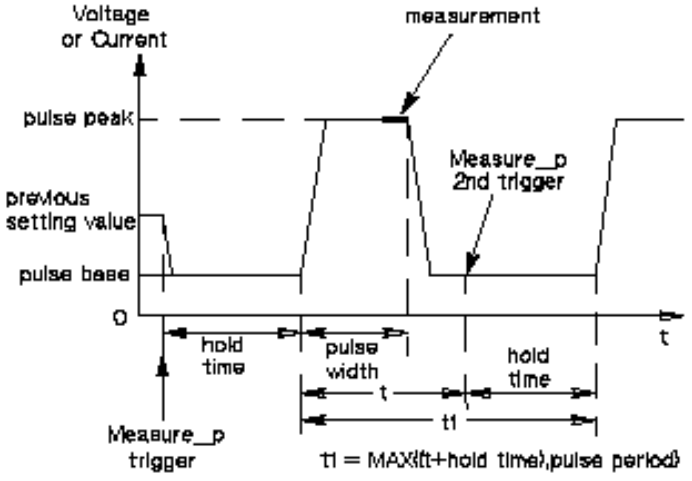

Figure 1 Pulse Base, Width, and Period in Pulsed Spot Measurements

HP 4140 pA Meter / DC Voltage Source

The HP 4140 is equipped with 2 DC voltage source units and 1 low current measurement unit. The units take measurements in either the internal system or user sweep mode.

IC-CAP assigns the following names to the units:

VA	DC Voltage Source Unit. VA supports internal linear sweeps using step or ramp sweep mode. This unit can also be used in user sweep mode.
VB	DC Voltage Source Unit. VB only sources a constant voltage. If VB is assigned to the main sweep, user sweep mode is required.
LCU	pA Current Monitor Unit.

The HP 4140 driver is an example of a driver created using the *Open Measurement Interface*. The driver's source code can be found in the files *user_meas2.h* and *user_meas2.C* in the directory *$ICCAP_ROOT/src*. For information, refer to Chapter 2, "Drivers."

To recognize which data delimiter (CR/LF or Comma) is used, IC-CAP performs a spot I measurement only when an HP 4140 is first accessed (when the *Measure* command is issued). When the data delimiter is changed, choose *Rebuild* in the Hardware Setup window so that IC-CAP will note the change.

With a ramp sweep, measured current I can be translated into quasi-static C by the following equation. Use a transform to perform this calculation.

$$C = \frac{I}{RampRate}[Farads]$$

The following table describes the HP 4140 options and their default values, where applicable.

Table 2 HP 4140 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use the instrument's internal sweep. Default = No
Hold Time	Time the instrument waits before starting an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. The range is 0.1 to 1999 seconds in 100 msec steps. Default = 0.1
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. The range is 0.01 to 100 seconds in 10 msec steps. Default = 0.01 seconds
Integ Time	Instrument integration time: S (short), M (medium), or L (long). Default = L
Range	Specifies the measurement range. 0 is auto range; 1 is range hold; 2 to 12 denotes a current range of 1E-2 to1 E-12. For a faster ramp rate, use a fixed range. Default = 0
Use Ramp Sweep	Yes = use ramp sweep. No = use step sweep. With a ramp sweep, both start and stop values are expanded by 1 point to have the same number of measurement points with a step sweep. Default = No
Ramp Rate	The dV/dt value of a ramp sweep. Minimum is 0.001V/s; maximum is 1V/s. Default = 0.5
Init Command	This command field is used to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP 4141 DC Source / Monitor

The HP 4141 is equipped with 4 stimulus/measurement units (SMU), 2 programmable voltage source units (VS), 2 voltage monitor units (VM) and 1 non-programmable ground unit. Use a 16059A Adaptor when measuring a device with a 16058A Test Fixture.

IC-CAP assigns the following names to the units:

SMUn	Stimulus / Measurement Unit n (1, 2, 3, 4)
VSn	Voltage Source Unit n (1, 2)
VMn	Voltage Monitor Unit n (1, 2)

The following table describes the HP 4141 options and their default values, where applicable.

Table 3 HP 4141 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use the instrument's internal sweep. Default = No
Hold Time	Time the instrument waits before starting internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay / hold options set in other instrument drivers running on the same test system. Range is 0 to 650 seconds in 10 msec steps. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay / hold options set in other instrument drivers running on the same test system. Range is 0 to 6.5 seconds in 1 msec steps. Default = 0
Integ Time	Instrument integration time; set to S (short), M (medium), or L (long). Default = S

Table 3 HP 4141 Options (continued)

Option	Description
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP / Agilent 4142 Modular DC Source / Monitor

The 4142 contains 8 configurable plug-in slots for:

- High-power stimulus/measurement units (HPSMU)
- Medium-power stimulus/measurement units (MPSMU)
- High current unit (HCU), high voltage unit (HVU)
- Voltage source units (VS)
- Voltage monitor units (VM)
- Analog Feedback units (AFU—not supported by IC-CAP)

The 4142 ground unit (GND) provides a means for connecting device terminals to a ground reference and can sink current up to 1.6A. This ground unit cannot be programmed or monitored.

Unit names are dependent on the slot they occupy. An SMU (except MPSMU) uses 2 slots in the mainframe; the value of slot number *n* is the higher of the 2 slots. IC-CAP assigns the following names to the units:

MPSMUn	Medium Powered Stimulus / Measurement Unit in slot n
HPSMUn	High Powered Stimulus / Measurement Unit in slot n
HCUn	High Current Stimulus / Measurement Unit in slot n
HVUn	High Voltage Stimulus / Measurement Unit in slot n
VSmn	Voltage Source Unit m (1 or 2) in slot n
VMmn	Voltage Monitor Unit m (1 or 2) in slot n

The 4142 has a total maximum power consumption of 32W for HPSMU, MPSMU, HCU, HVU and VS/VM. If a measurement is performed and the 32W limit is exceeded, the measurement will not be attempted and IC-CAP will issue an error message. Power consumed by the VS/VM unit (HP/Agilent 41424A) is 2.2W at the 20V range and 0.88W at the 40V range. When using SMUs to source either voltage or current, refer to the *Agilent 4142 Operation Manual* for the actual SMU power calculations.

NOTE To save power, IC-CAP disconnects output switches of unused HCUs and HVUs when they are not used with the current Setup.

In the user and the internal system mode, voltage and current pulsed measurements are supported. Quasi-pulsed spot measurement is not supported by IC-CAP. For information on how to set up a pulsed measurement, refer to the *Pulse* entries in Table 5.

HCU and 2-channel pulsed measurements are supported with ROM version 3.0 and later; HVU is supported with version 4.0 and later; Module Selector requires version 4.1.

SMU

Current-forced SMUs of the same type can be connected in parallel to increase the output current. Use SYNC sweep if you want double current at each sweep point. System Sweep can be used for 2 HPSMUs; however, User Sweep must be used for 2 HCUs. To avoid a warning message, set the system variable *PARALLEL_INPUT_UNITS_OK* to *True*.

HCU

An HCU can force up to 10A with 10V in the pulse mode only. Its pulse base is fixed to zero and it cannot force a constant value. Both 1- and 2-channel measurements are supported with an HCU.

1-Channel Pulse Because an HCU can force only a pulse, an HCU can be used without placing its name in the pulse unit field in the Instrument Options folder. This is called an implicit pulse channel and its pulse width and period are taken from the Instrument Options folder. The pulse base is always set to zero for an implicit pulse channel (HCU). The pulse width and pulse period of an HCU have a different specification from other units. The pulse width must be 0.1 to 1 msec; the pulse period must be 10 to 500 msec; the pulse duty must be 10 percent or less when its output or compliance current is 1A or less, and must be 1 percent or less when its current is more than 1A.

If an HCU is specified as the pulse unit explicitly in the Instrument Options folder, this is called an explicit pulse channel and the pulse base in the Instrument Options folder must be set to zero.

2-Channel Pulse When 2 pulsed channels are used, the primary channel must be an HCU; the secondary channel can be an HCU, SMU, or VS—it cannot be an HVU. For information on the 2-channel configuration, refer to the following table.

Table 4 2-Channel Options

Channel	Primary	Secondary
Pulse Unit	HCU only	HCU/SMU/VS
Pulse Width	0.1 to 0.8 msec; from Instrument Options folder	approximately 1 msec
Pulse Period	from Instrument Options folder	from Instrument Options folder
Pulse Base	0 only	from Instrument Options folder
Declared	implicit	from Instrument Options folder

HVU

An HVU can force up to 1000V with 10 mA in either the constant or the pulsed mode. This unit has the same specification about the pulse width, pulse period, and pulse duty as other SMUs.

An HVU is a unipolar source that requires the output polarity be set before you set its output value. An internal sweep from the minus-to-plus or from the plus-to-minus region is impossible; set the *Use User Sweep* option to *Yes,* if such a sweep range is necessary.

To perform the self test and calibration, the INTLK switch must be closed for an HVU. At the start and end of each measurement, IC-CAP instructs all used units to force zero for safety reasons. The *shock hazard* lamp of the HP/Agilent 16088B test fixture remains on after each measurement because the output switch of the used HVU has been closed to force zero.

VM

A differential voltage measurement of a VM unit is supported by supplying a command string to the *Init Command* field in the Instrument Options folder. If a VM unit is in slot 8, add the command string "VM 8,2;" to the *Init Command* field. This sets the VM unit at slot 8 to a differential mode where it measures the differential voltage of VM18 versus VM28. Then add an output for VM18 (not VM28) to the Setup. When simulating this differential mode VM, VM18 should correspond to the + Node to have the same polarity between measurement and simulation.

The following table describes the HP/Agilent 4142 options and their default values, where applicable.

Table 5 HP/Agilent 4l42 Options

Option	Description
Use User Sweep	Yes = use user mode sweep. No = use system mode, when all required conditions are met. Default = No
Hold Time	Time to allow for DC settling before starting internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 655 seconds. Default = 0

Table 5 HP/Agilent 4l42 Options (continued)

Option	Description
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 65 seconds. Default = 100 msec
Integ Time	Instrument's integration time; can be set to S (short), M (medium), or L (long). Default = S
Range	Specifies the measurement range. 0 specifies auto range. Applies to all SMUs in this 4142. Refer to the *Agilent 4142 Operation Manual* for definitions of other ranges. Default = 0
SMU Filters ON	Yes = filters ON. No = filters OFF. Applies to all SMUs in this 4142. A pulsed unit is automatically set to filter off. Default = Yes
Pulse Unit	Enter name of a pulsed unit when taking pulsed measurements.
Pulse Base	Enter value of pulse base.
Pulse Width	Enter value of pulse width.
Pulse Period	Enter value of pulse period.
Module Control	Enter *SMU*, *HCU*, or *HVU* for module selection with option 300. For user relays, enter an exact argument for the ERC command (for example, *2,1,0*). When blank, no unit is connected by the module selector. Refer to the *4142 GPIB Command Reference Manual* for the ERC command.
Init Command	Command field used to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none
Power Compliance †	Specify power compliance in Watts with 1mW resolution. Specifying 0 (zero) disables power compliance mode (default).

Table 5 HP/Agilent 4l42 Options (continued)

Option	Description
†	Supported for internal sweep mode only (USE USER SWEEP = NO) and DC only measurement setups. This option applies to SMUs only. The allowable range of power compliance depends on the sweep source (SMU type) and is not monitored by IC-CAP. Refer to instrument's documentation for more details. IC-CAP requires rectangular datasets, thus when a power compliance is specified, the instrument concludes the measurement at the power compliance limit, but IC-CAP fills the datasets with the last point measured below power compliance.

HP 4145 Semiconductor Parameter Analyzer

The HP 4145 is equipped with the following units:

- Four programmable stimulus/measurement units (SMU)
- Two programmable voltage source units (VS)
- Two voltage monitor units (VM)

Time-domain measurement is not supported by IC-CAP.

NOTE A user-defined function may cause an error E07 in the HP 4145 when the function refers to non-existing source names. Clear any user-defined functions in the HP 4145 before making a measurement with IC-CAP.

IC-CAP assigns the following names to the units:

SMUn	Stimulus/Measurement Unit n (1, 2, 3, 4)
VSn	Voltage Source Unit n (1, 2)
VMn	Voltage Monitor Unit n (1, 2)

To recognize which data delimiter (CR/LF or Comma) is used, IC-CAP performs a 2-point VM measurement only when an HP 4145 is first accessed (when the *Measure* command is

issued). When the data delimiter is changed, choose *Rebuild* in the Hardware Setup window so that IC-CAP will note the change.

NOTE The HP 4145 performs an internal logarithmic sweep only if the number of points per decade is 10, 25 or 50; otherwise IC-CAP will force the measurement into User Sweep. If a Setup contains only a single Input with a sweep order of 1, IC-CAP will force the measurement into User Sweep.

HP 4145 requires its test fixture lid be closed in User Sweep mode for safety reasons, even though output is low. A Shorting Connector (P/N 04145-61623) can be used to bypass this lid closure check.

NOTE The HP 4145 offers the internal secondary sweep capability known as VAR2. However, the internal SYNC sweep always depends on the primary sweep source VAR1. When a secondary SYNC sweep is desired, use *User Sweep*.

NOTE Always fill the Node Name field of each Input in a Setup because the HP 4145 needs a channel name generated from a Node Name. The channel names must be unique within a Setup for the HP 4145 internal sweep mode.

The following table describes the HP 4145 options and their default values, where applicable.

Table 6 HP 4145 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use the instrument's internal sweep. Default = No

Table 6 HP 4145 Options

Option	Description
Hold Time	Time the instrument waits before starting an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Range is 0 to 650 sec in 10 msec steps. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. The range is 0 to 6.5 sec in 1 msec steps. Default = 0
Integ Time	Instrument integration time; set to S (short), M (medium), or L (long). Default = S
Init Command	This command field is used to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP / Agilent 4155 Semiconductor Parameter Analyzer

The HP/Agilent 4155 is equipped with the following units:

- Four programmable medium power stimulus/measurement units (MPSMU)
- Two programmable voltage source units (VS)
- Two voltage monitor units (VM)

IC-CAP assigns the following names to the units:

MPSMUn	Medium Power Stimulus / Measurement Unit n (1, 2, 3, 4)
VSUx	Voltage Source Unit n (1, 2)
VMUx	Voltage Monitor Unit n (1, 2)

The HP 41501A is an optional SMU and pulse generator expander box that can be attached to and controlled by the 4155. The HP 41501A can be equipped with a high power stimulus/measurement unit (HPSMU), medium power stimulus/measurement units (MPSMU), and pulse generator units (PGU) (IC-CAP does not support PGUs). The availability and combination of these units depends on the expander box option.

NOTE

When making pulsed mode measurements, if you specify an SMU as the unit for an Output, and there is no corresponding SMU unit for an Input, compliance errors will result. The same problem occurs if you specify Voltage Monitor units. To prevent this from happening, you should define a compliance value for Output-only SMUs and a measurement range for Voltage Monitor units (VMs) through system variables, as follows, using the unit name:

HRSMUx_COMP HPSMUx_COMP MPSMUx_COMP

where x = 1, 2, 3, 4, 5, 6

VMU1_RANGE_VALUE VMU2_RANGE_VALUE

IC-CAP assigns the following names to the units of the optional HP 41501A:

- MPSMUn Medium Power Stimulus/Measurement Unit n (5, 6)
- HPSMU5 High Power Stimulus/Measurement Unit

A ground unit (GNDU) provides a means for connecting device terminals to a ground reference and can sink up to 1.6A. The ground unit is supported by IC-CAP but will not appear in the Hardware Editor Configuration dialog box. For information on how to use the ground unit, refer to the section "Adding a Ground Unit" in the *User's Guide*.

In both the user and internal sweep mode, voltage and current pulsed measurements are supported. Only the SMUs can be specified as pulse units because the PGUs are not currently supported. For information on how to set up a pulsed measurement, refer to the *Pulse* options in Table 7.

NOTE The HP/Agilent 4155 offers the internal secondary sweep capability known as VAR2. However, the internal SYNC sweep always depends on the primary sweep source VAR1. When a secondary SYNC sweep is desired, use *User Sweep*.

NOTE To execute a user sweep measurement, IC-CAP sets the HP/Agilent 4155 to the Sampling mode with the number of samples equal to 1. The front panel screen activity is turned off at the start of the measurement and is turned back on after the measurement is completed.

Although the 4155 performs an internal logarithmic sweep if the number of points per decade is 10, 25 or 50, IC-CAP will force the measurement into the User Sweep for all specified logarithmic sweeps. If a Setup specification contains a single Input with a sweep order of 1, IC-CAP will force the measurement into User Sweep.

The following table describes the 4155 options and their default values, where applicable.

Table 7 HP/Agilent 4155 (and HP/Agilent 4156) Option

Option	Description
Use User Sweep	Yes = use user mode sweep. No = use system mode, when required conditions are met. Default = No
Hold Time	Time delay before starting an internal or user sweep to allow for DC settling. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum is 655 seconds. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. This value is not used for pulsed sweeps. Maximum is 65 seconds. Default = 0
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Integ Time	Instrument integration time; set to S (short), M (medium), or L (long). Default = S
Pulse Unit	Enter the name of a pulsed unit when taking pulsed measurements.
Pulse Base	Enter the value of the pulse base.
Pulse Width	Enter the value of the pulse width.
Pulse Period	Enter the value of the pulse period.
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none
Power Compliance †	Specify power compliance in Watts with 1mW resolution. Specifying 0 (zero) disables power compliance mode (default).

Table 7 HP/Agilent 4155 (and HP/Agilent 4156) Option (continued)

Option	Description
Notes: † Supported for internal sweep mode only (USE USER SWEEP = NO) and DC only measurement setups. This option applies to SMUs only. The allowable range of power compliance depends on the sweep source (SMU type) and is not monitored by IC-CAP. Refer to instrument's documentation for more details. IC-CAP requires rectangular datasets, thus when a power compliance is specified, the instrument concludes the measurement at the power compliance limit, but IC-CAP fills the datasets with the last point measured below power compliance.	

HP/Agilent 4156 Precision Semiconductor Parameter Analyzer

The HP/Agilent 4156 is equipped with the following units:

- Four programmable high-resolution stimulus/measurement units (HRSMU)
- Two programmable voltage source units (VS)
- Two voltage monitor units (VM)

This instrument is designed for Kelvin connections and is capable of low- resistance and low-current measurements.

IC-CAP assigns the following names to the units:

HRSMUn	High Resolution Stimulus/Measurement Unit n (1, 2, 3, 4)
VSUx	Voltage Source Unit n (1, 2)
VMUx	Voltage Monitor Unit n (1, 2)

The HP 41501A is an optional SMU and pulse generator expander box that can be attached to and controlled by the 4156. The HP 41501A can be equipped with the following units:

- High-power stimulus/measurement unit (HPSMU)
- Medium power stimulus/measurement units (MPSMU)
- Pulse generator units (PGU—not supported by IC-CAP)

IC-CAP assigns the following names to the units of the optional HP 41501A:

MPSMUn	Medium Power Stimulus/Measurement Unit n (5, 6)
HPSMU5	High Power Stimulus/Measurement Unit

A ground unit (GNDU) provides a means for connecting device terminals to a ground reference and can sink up to 1.6A. The ground unit is supported by IC-CAP but will not appear in the Hardware Editor Configuration dialog box. For information on how to use the ground unit, refer to the section "Adding a Ground Unit" in the *User's Guide*.

In both the user and internal sweep mode, voltage and current pulsed measurements are supported. Only the SMUs can be specified as pulse units because PGUs are not currently supported. For information on how to set up a pulsed measurement, refer to the *Pulse* options in Table 7.

NOTE The HP/Agilent 4156 offers the internal secondary sweep capability known as VAR2. However, the internal SYNC sweep always depends on the primary sweep source VAR1. When a secondary SYNC sweep is desired, use *User Sweep*.

NOTE To execute a user sweep measurement, IC-CAP sets the HP/Agilent 4156 to the Sampling mode with the number of samples equal to 1. The front panel screen activity is turned off at the start of the measurement and is turned back on after the measurement is completed.

NOTE Although the HP/Agilent 4156 performs an internal logarithmic sweep if the number of points per decade is 10, 25 or 50, IC-CAP will force the measurement into the user sweep for all specified logarithmic sweeps. If a Setup specification contains a single Input with a sweep order of 1, IC-CAP forces the measurement into user sweep.

Options for the HP 4156 are the same as for the HP 4155; refer to Table 7.

Agilent E5260 Series Parametric Measurement Solutions

Agilent E5260 Series High Speed Measurement Solutions are built around the following:

- E5260A 8-slot parametric measurement mainframe
- E5262A/3A 2-channel source/monitor units

Available Source/Monitor Units (SMUs):

- E5290A High Power source/monitor unit (HPSMU)
- E5291A Medium Power source/monitor unit (MPSMU)

The E5260A 8-slot parametric measurement mainframe holds up to 8 single-slot modules, such as a medium power source/monitor unit (MPSMU), or up to 4 dual-slot modules, such as a high power source/monitor unit (HPSMU).

The E5262A 2-channel source/monitor unit contains 2 medium power source/monitor units (SMUs).

The E5263A 2-channel source/monitor unit contains 1 high power and 1 medium power SMU.

If you install 4 HPSMUs into the E5260A mainframe, you can output 1 Amp of current from each of these units simultaneously.

The E5260A/B mainframe's ground unit (GNDU) provides a means for connecting device terminals to a ground reference. The GNDU will sink 4 amps of current without having to worry about any resistive ground rise issues. This ground unit cannot be programmed or monitored.

Unit names are dependent on the slot they occupy. A high power SMU occupies 2 slots in the mainframe, a medium or a high resolution SMU occupies 1 slot; the value of slot number n is the higher of the 2 slots. IC-CAP assigns the following names to the units:

MPSMUn	Medium Powered Stimulus/Measurement Unit in slot n

HPSMUn	High Powered Stimulus/Measurement Unit in slot n

The E5260A 8-slot parametric measurement mainframe has a total maximum power consumption of 80W for all plug-in modules. The total maximum power consumption limits for the E5262A and E5263A are 8W and 24W respectively. If a measurement is performed and the power limitation is exceeded, the measurement will not be attempted and IC-CAP will issue an error message.

HPSMU

The high power source monitor units will provide up to 50 milliamps of current at ±200 volts and 1 amp of current at ±40 volts. Up to 4 HPSMUs can be used at one time in the E5260A mainframe. See manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

MPSMU

The medium power source monitor units will provide up to 20 milliamps of current at ±200 volts and 200 milliamps of current at ±20 volts. Up to 8 MPSMUs can be used at one time in the E5260A. See manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

Instrument Options

The following table describes the Agilent E5260A options and their default values, where applicable.

Table 8 Agilent E5260A Options

Option	Description
Use User Sweep	Yes = use user mode sweep. No = use internal sweep, when all required conditions are met. Default = No

Table 8 Agilent E5260A Options (continued)

Option	Description
Hold Time	Time to allow for DC settling before starting internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 655 seconds. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 65 seconds. Default = 100 msec
Integ Time	Instrument's integration time; can be set to S (short), M (medium), or L (long). Default = S
Power Compliance †	Specify power compliance in Watts with 1mW resolution. Specifying 0 (zero) disables power compliance mode (default).
SMU Filters ON	Yes = filters ON, No = filters OFF. Applies to all SMUs in this E5260. Default = No
Range Manager Mode	Specify Range Manager mode: 1, 2, or 3. 1 = deactivate Range Manager (default) 2 = set Range Manager to mode 2 3 = set Range Manager to mode 3 The Range Manager command is used to avoid potential voltage spikes during current range switching when using autorange. See Instrument Programming Guide††† under RM command for details.
Range Manager Setting	Set the rate of the Range Manager command. Allowed values are between 11 and 100. This option is only active when Range Manager Mode is set to 2 or 3.
Enable <SMU name> Range Manager	Enables Range Manager at the setting values entered above for the named SMU. Default = No.

Table 8 Agilent E5260A Options (continued)

Option	Description
<SMU name> In/Out Range	Specify force (Input Sweep) and Output measurement ranges. Default is autorange (0 or 0/0) for both Input and Output measurement ranges. When an SMU is used in an IC-CAP input definition to force voltage or current, a specific force range may be selected. The force resolution[††] will depend on the selected range. When an SMU is used in an IC-CAP output definition to monitor voltage or current, a specific measurement range may be selected. The measurement resolution will depend on the selected range. Both fixed (negative range number) and limited auto (positive numbers) ranges are supported. Allowed ranges are SMU dependent and are forced by IC-CAP during initial measurement setup. See instrument manual[†††] for allowed values for each SMU. When instrument supports 2 values for setting the same range, IC-CAP only supports the smaller of the 2. For example, to select a 20 V range, the manual suggests using 12 or 200. Use the value 12, to select that range. Ranges must be in the format ForceRange/OutRange, e.g., 13/15 for a voltage SMU monitoring current means Force Voltage Range=13 (40 V, 2mV resolution), Output Current Measurement Range=15 (10 uA limited autorange).
Pulse Unit	Enter name of a pulsed unit when taking pulsed measurements.
Pulse Base	Enter value of pulse base.
Pulse Width	Enter value of pulse width.
Pulse Period	Enter value of pulse period.
Disable Self-Cal	Controls the status of the E5260A self-calibration routine during measurements. Yes = self-cal disabled. No= self-cal enabled. Default = No.
Output I/O Port (ERC Command)	Send the user string with the ERC command
Output I/O Port (ERM Command)	Send the user string with the ERM command
Delay for timeouts	Sets the delay before a measurement attempt times out.

Table 8 Agilent E5260A Options (continued)

Option	Description
Init Command	Command field used to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

† Supported for internal sweep mode only (USE USER SWEEP = NO) and DC only measurement setups.

The allowable range of power compliance depends on the sweep source (SMU type) and is not monitored by IC-CAP. Refer to instrument's documentation for more details.

IC-CAP requires rectangular datasets, thus when a power compliance is specified, the instrument concludes the measurement at the power compliance limit, but IC-CAP fills the datasets with the last point measured below power compliance.

†† Agilent E5260A, E5262A, E5263A Technical Overview—see Medium and High Power SMUs technical specifications.

††† Agilent E5260A series Programming Guide—Chapter 4 “Command Reference”—Section “Command Parameters”

Agilent E5270 Series Parametric Measurement Solutions

Agilent E5270 Series Parametric Measurement Solutions are built around the following:

- E5270A 8-slot parametric measurement mainframe (obsolete)
- E5270B 8-slot parametric measurement mainframe
- E5272A/3A 2-channel source/monitor units (obsolete)

Available Source/Monitor Units (SMUs):

- E5280A High Power source/monitor unit (HPSMU) for E5270A only
- E5280B High Power source/monitor unit (HPSMU) for E5270B only
- E5281A Medium Power source/monitor unit (MPSMU) for E5270A only

- E5281B Medium Power source/monitor unit (MPSMU) for E5270B only
- E5287A High Resolution source/monitor unit (HRSMU) for E5270B only

The E5270A 8-slot parametric measurement mainframe holds up to 8 single-slot modules, such as a medium power source/monitor unit (MPSMU), or up to 4 dual-slot modules, such as a high power source/monitor unit (HPSMU).

The E5270B 8-slot parametric measurement mainframe holds up to 8 single-slot modules, such as a medium power source/monitor unit (MPSMU, HRSMU), or up to 4 dual-slot modules, such as a high power source/monitor unit (HPSMU).

The E5272A 2-channel source/monitor unit contains 2 medium power source/monitor units (SMUs).

The E5273A 2-channel source/monitor unit contains 1 high power and 1 medium power SMU.

If you install 4 HPSMUs into E5270A/B mainframes, you can output 1 Amp of current from each of these units simultaneously.

The E5270A/B mainframe's ground unit (GNDU) provides a means for connecting device terminals to a ground reference. The GNDU will sink 4 amps of current without having to worry about any resistive ground rise issues. This ground unit cannot be programmed or monitored.

Unit names are dependent on the slot they occupy. A high power SMU occupies 2 slots in the mainframe, a medium or a high resolution occupies 1 slot; the value of slot number n is the higher of the 2 slots. IC-CAP assigns the following names to the units:

MPSMUn	Medium Powered Stimulus/Measurement Unit in slot n
HPSMUn	High Powered Stimulus/Measurement Unit in slot n
HRSMUn	High Resolution Source/Monitor Unit in slot n (E5270B only)

The E5270A and E5270B 8-slot parametric measurement mainframes have a total maximum power consumption of 80W for all plug-in modules. The total maximum power consumption limits for the E5272A and E5273A are 8W and 24W respectively. If a measurement is performed and the power limitation is exceeded, the measurement will not be attempted and IC-CAP will issue an error message.

HPSMU

The high power source monitor units will provide up to 50 milliamps of current at ±200 volts and 1 amp of current at ±40 volts. Up to 4 HPSMUs can be used at one time in the E5270A mainframe. Since SMUs characteristic may vary with version, see manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

MPSMU

The medium power source monitor units will provide up to 20 milliamps of current at ±100 volts and 100 milliamps of current at ±20 volts (200 mA for the E5281A). Up to 8 MPSMUs can be used at one time in the E5270A and E5270B mainframes. Since SMUs characteristic may vary with version, see manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

HRSMU

The medium power/high resolution source monitor units provide up to 20 milliamps of current at ±100 volts and 100 milliamps of current at ±20 volts. Up to 8 HRSMUs can be used at one time in the E5270B mainframe. In the lowest current range, 10 pA, HRSMU's current force resolution can be as low as 5 fA with a measurement resolution as low as 1 fA.

Instrument Options

The following table describes the Agilent E5270A/B options and their default values, where applicable.

Table 9 Agilent E5270A/B Options

Option	Description
Use User Sweep	Yes = use user mode sweep. No = use internal sweep, when all required conditions are met. Default = No
Hold Time	Time to allow for DC settling before starting internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 655 seconds. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 65 seconds. Default = 100 msec
Integ Time	Instrument's integration time; can be set to S (short), M (medium), or L (long). Default = S
Power Compliance †	Specify power compliance in Watts with 1mW resolution. Specifying 0 (zero) disables power compliance mode (default).
SMU Filters ON	Yes = filters ON, No = filters OFF. Applies to all SMUs in this E5270. Default = No
Range Manager Mode	Specify Range Manager mode: 1, 2, or 3. 1 = deactivate Range Manager (default) 2 = set Range Manager to mode 2 3 = set Range Manager to mode 3 The Range Manager command is used to avoid potential voltage spikes during current range switching when using autorange. See Instrument Programming Guide††† under RM command for details.
Range Manager Setting	Set the rate of the Range Manager command. Allowed values are between 11 and 100. This option is only active when Range Manager Mode is set to 2 or 3.
<SMU name> A/D converter	Sets A/D converter for higher resolution or higher speed. S = higher speed R = higher resolution (Default)

Table 9 Agilent E5270A/B Options (continued)

Option	Description
Enable <SMU name> Range Manager	Enables Range Manager at the setting values entered above for the named SMU. Default = No.
<SMU name> In/Out Range	Specify force (Input Sweep) and Output measurement ranges. Default is autorange (0 or 0/0) for both Input and Output measurement ranges. When an SMU is used in an IC-CAP input definition to force voltage or current, a specific force range may be selected. The force resolution[††] will depend on the selected range. When an SMU is used in an IC-CAP output definition to monitor voltage or current, a specific measurement range may be selected. The measurement resolution will depend on the selected range. Both fixed (negative range number) and limited auto (positive numbers) ranges are supported. Allowed ranges are SMU dependent and are forced by IC-CAP during initial measurement setup. See instrument manual[†††] for allowed values for each SMU. When instrument supports 2 values for setting the same range, IC-CAP only supports the smaller of the 2. For example, to select a 20 V range, the manual suggests using 12 or 200. Use the value 12, to select that range. Ranges must be in the format ForceRange/OutRange, e.g., 13/15 for a voltage SMU monitoring current means Force Voltage Range=13 (40 V, 2mV resolution), Output Current Measurement Range=15 (10 uA limited autorange).
Pulse Unit	Enter name of a pulsed unit when taking pulsed measurements.
Pulse Base	Enter value of pulse base.
Pulse Width	Enter value of pulse width.
Pulse Period	Enter value of pulse period.
Disable Self-Cal	Controls the status of the E5270A self-calibration routine during measurements. Yes = self-cal disabled. No= self-cal enabled. Default = No.
Output I/O Port (ERC Command)	Send the user string with the ERC command

Table 9 Agilent E5270A/B Options (continued)

Option	Description
Output I/O Port (ERM Command)	Send the user string with the ERM command
Delay for timeouts	Sets the delay before a measurement attempt times out.
Init Command	Command field used to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

† Supported for internal sweep mode only (USE USER SWEEP = NO) and DC only measurement setups.

The allowable range of power compliance depends on the sweep source (SMU type) and is not monitored by IC-CAP. Refer to instrument's documentation for more details.

IC-CAP requires rectangular datasets, thus when a power compliance is specified, the instrument concludes the measurement at the power compliance limit, but IC-CAP fills the datasets with the last point measured below power compliance.

†† Agilent E5270A, E5272A, E5273A Technical Overview—see Medium and High Power SMUs technical specifications.

††† Agilent E5270A series Programming Guide—Chapter 4 “Command Reference”—Section “Command Parameters”

Agilent B1500A Semiconductor Device Analyzer

The Agilent B1500A Semiconductor Device Analyzer is a modular instrument with a ten-slot configuration that supports both IV and CV measurements.

The B1500A driver supports the following plug-in modules:

- B1510A High Power Source Monitor Unit Module (HPSMU) for B1500
- B1511A Medium Power Source Monitor Unit Module (MPSMU) for B1500
- B1517A High Resolution Source Monitor Unit Module (HRSMU) for B1500

The B1500A driver does *NOT* support the following plug-in modules:

- B1520A Multi-Frequency Capacitance Measurement Unit Module for B1500 (combined DC-CV measurements not supported)
- E5288A Auto Sense and Switch Unit for B1500

HPSMU

The high power source monitor units will provide up to 1 amp of current at ±200 volts. Up to 4 HPSMUs can be used at one time in the B1500A. Since SMUs characteristic may vary with version, see manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

MPSMU

The medium power source monitor units will provide up to 100 milliamps of current at ±100 volts. Up to 10 MPSMUs can be used at one time in the B1500A. Since SMUs characteristic may vary with version, see manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

HRSMU

The medium power/high resolution source monitor units provide up to 100 milliamps of current at ±100 volts. Up to 10 HRSMUs can be used at one time in the B1500A. Since SMUs characteristic may vary with version, see manual for complete measurement and force ranges specifications such as resolution and measurement accuracy.

Instrument Options

The following table describes the Agilent B1500A options and their default values, where applicable.

Table 10 Agilent B1500A Options

Option	Description
Use User Sweep	Yes = use user mode sweep. No = use internal sweep, when all required conditions are met. Default = No
Hold Time	Time to allow for DC settling before starting internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 655 seconds. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instrument drivers running on the same test system. Maximum 65 seconds. Default = 100 msec
Integ Time	Instrument's integration time; can be set to S (short), M (medium), or L (long). Default = S
Power Compliance †	Specify power compliance in Watts with 1mW resolution. Specifying 0 (zero) disables power compliance mode (default).
SMU Filters ON	Yes = filters ON, No = filters OFF. Applies to all SMUs in this E5270. Default = No

Table 10 Agilent B1500A Options (continued)

Option	Description
Range Manager Mode	Specify Range Manager mode: 1, 2, or 3. 1 = deactivate Range Manager (default) 2 = set Range Manager to mode 2 3 = set Range Manager to mode 3 The Range Manager command is used to avoid potential voltage spikes during current range switching when using autorange. See Instrument Programming Guide††† under RM command for details.
Range Manager Setting	Set the rate of the Range Manager command. Allowed values are between 11 and 100. This option is only active when Range Manager Mode is set to 2 or 3.
<SMU name> A/D converter	Sets A/D converter for higher resolution or higher speed. S = higher speed R = higher resolution (Default)
Enable <SMU name> Range Manager	Enables Range Manager at the setting values entered above for the named SMU. Default = No.

Table 10 Agilent B1500A Options (continued)

Option	Description
<SMU name> In/Out Range	Specify force (Input Sweep) and Output measurement ranges. Default is autorange (0 or 0/0) for both Input and Output measurement ranges. When an SMU is used in an IC-CAP input definition to force voltage or current, a specific force range may be selected. The force resolution†† will depend on the selected range. When an SMU is used in an IC-CAP output definition to monitor voltage or current, a specific measurement range may be selected. The measurement resolution will depend on the selected range. Both fixed (negative range number) and limited auto (positive numbers) ranges are supported. Allowed ranges are SMU dependent and are forced by IC-CAP during initial measurement setup. See instrument manual††† for allowed values for each SMU. When instrument supports 2 values for setting the same range, IC-CAP only supports the smaller of the 2. For example, to select a 20 V range, the manual suggests using 12 or 200. Use the value 12, to select that range. Ranges must be in the format ForceRange/OutRange, e.g., 13/15 for a voltage SMU monitoring current means Force Voltage Range=13 (40 V, 2mV resolution), Output Current Measurement Range=15 (10 uA limited autorange).
Pulse Unit	Enter name of a pulsed unit when taking pulsed measurements.
Pulse Base	Enter value of pulse base.
Pulse Width	Enter value of pulse width.
Pulse Period	Enter value of pulse period.
Disable Self-Cal	Controls the status of the E5270A self-calibration routine during measurements. Yes = self-cal disabled. No= self-cal enabled. Default = No.
Output I/O Port (ERC Command)	Send the user string with the ERC command
Output I/O Port (ERM Command)	Send the user string with the ERM command
Delay for timeouts	Sets the delay before a measurement attempt times out.

Table 10 Agilent B1500A Options (continued)

Option	Description
Init Command	Command field used to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

† Supported for internal sweep mode only (USE USER SWEEP = NO) and DC only measurement setups.

The allowable range of power compliance depends on the sweep source (SMU type) and is not monitored by IC-CAP. Refer to instrument's documentation for more details.

IC-CAP requires rectangular datasets, thus when a power compliance is specified, the instrument concludes the measurement at the power compliance limit, but IC-CAP fills the datasets with the last point measured below power compliance.

†† Agilent B1500A Technical Overview—see Medium and High Power SMUs technical specifications.

††† Agilent B1500A series Programming Guide—Chapter 4 “Command Reference”—Section “Command Parameters”

Configuring the B1500A for IC-CAP Remote Contol

1 Turn on the B1500.

2 Login into Windows but do not start the EasyExpert software.

3 Start the Agilent_Connection_Expert:

Select **Start** > **Programs** > **Agilent_IO_Library_Suites** > **Agilent_Connection_Expert.**

4 Select **GPIB0** > **Change_Properties**, then *uncheck* the following checkboxes:

- *System_Controller*
- *Auto-Discover_Instruments_Connected_To_The_Interface*

Select **OK** and exit the dialog.

5 Reboot the B1500A when prompted.

6 Start the EasyExpert software:

Select **Start** > **Start_EasyExpert**.

Do not press the B1500A *Start* button, but leave the B1500A *Start* button on the screen.

NOTE

Fully starting the EasyExpert application would prevent IC-CAP from controlling the B1500A.

7 Connect the B1500A instrument to the IC-CAP computer via GPIB interface.

8 From IC-CAP, rebuild the active instrument list:

Select **Tools** > **Hardware Setup** > **Rebuild.**

9 After rebuild is completed, check that the B1500A is in the Active Instrument List.

10 Select the instrument and configure its SMU names according to the names used in your measurement setups.

Capacitance-Voltage Meters

Capacitance-voltage meters supported by IC-CAP are:

- HP 4194 Impedance Analyzer
- HP 4271 1 MHz Digital Capacitance Meter
- HP 4275 Multi-Frequency LCR Meter
- HP 4280 1 MHz Capacitance Meter
- HP/Agilent 4284 Precision LCR Meter
- HP/Agilent 4285 Precision LCR Meter
- Agilent E4980A Precision LCR Meter
- Agilent 4294A Precision Impedance Analyzer
- Agilent E4991A RF Impedance/Material Analyzer

For all capacitance-voltage meters, issue the *Calibrate* command before starting a measurement, otherwise calibration is carried out automatically at the start of the measurement.

This option directly controls the instrument firmware, and overrides similar delay/hold options set in other instruments' drivers running on the same test system.

Defining the Reset State

Using the *prepare_CV_meter.mdl* example model file, you can easily define the reset state for the following instruments:

- HP/Agilent 4284
- HP/Agilent 4285
- Agilent E4980

The IC-CAP drivers reset instruments to known states prior to configuring them for the current measurement. For the 4284, 4285 and E4980, it sends the *RST command, which resets the instruments to a known factory state. However, this default state (1V, 1KHz signal) may cause damage to certain devices between the time the $RST is requested and the time the requested signal level is set.

To avoid this problem, you can set the variable LCR_RST_MEM or LCR_RST_MEM_<unit> (e.g., LCR_RST_MEM_CM). The 4284, 4285, and E4980A instruments will use the value of this variable to set the instrument state. For example, if set to 1, the driver will recall instrument state 1 instead of *RST.

Using the *prepare_CV_meter.mdl* example model file, you can programatically set any state to be the *RST state with a zero signal level. It will also set the variable for you such that when a measurement is performed, this programatically set state is recalled instead of sending *RST.

To prepare a memory location, open and Auto Execute *model_files/misc/prepare_CV_meter.mdl*, then enter the 3 values below and click OK.

1 Name the unit associated with your instrument.

2 Identify the memory location (0-9 recommended, but you can use any number from 0-19 that your instrument supports.)

3 Indicate if you want the unit number to apply to any 4284, 4284, or E4980A, or only to those with the specified unit name. This selection essentially chooses between setting LCR_RST_MEM or LCR_RST_MEM_<unit>.

HP 4194 Impedance Analyzer

The HP 4194 offers 2 measurement types: impedance analysis and gain-phase measurement. These occupy different test connectors on the test set. IC-CAP supports the impedance analysis type, offering capacitance-voltage and conductance-versus-voltage measurements.

The frequency range is 100 Hz to 40 MHz; to extend this to 100 MHz use the impedance probe kit. An internal DC bias unit can deliver biases between –40V and +40V. An internal oscillator can deliver between 10 mV and 1V rms.

The HP 4194 driver is an example of a driver created using the *Open Measurement Interface*. The driver source code can be found in the files *user_meas.hxx* and *user_meas.cxx* in the directory *$ICCAP_ROOT/src*. For information, refer to Chapter 2, “Drivers.”

IC-CAP assigns the following name to the unit:

CM Capacitance Meter Unit

NOTE The short calibration of the HP 4194 driver is disabled by default because the CV measurement rarely needs this compensation. However, the SHORT_CAL4194 system variable may be defined and set to *Yes* to enable the short calibration.

NOTE After a CV measurement is finished, you may notice that a DC bias light on the HP 4194 stays on. This indicates that a bias voltage is still being applied to the test setup. However, the IC-CAP driver sets the DC sweep mode's bias voltage for the measurement so the DC bias is set to 0 V when the sweep starts and stops.

There are 2 ways you can verify the bias voltage is set to zero. One way is to measure the test setup with a DMM. Another way is to enable IC-CAP's Screen Debug (Tools > Options > Screen Debug) and see that the following commands are being sent to the CV meter:

```
START=0.0;STOP=0.0;NOP=2;MANUAL=0.0;OSC=0.01
SWM3;TRGM2
TRIG
```

The following table describes the HP 4194 options and their default values, where applicable.

Table 11 HP 4194 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use the instrument's internal sweep. Default = No
Hold Time	Time the instrument waits before starting an internal or user sweep. Default = 0

Table 11 HP 4194 Options (continued)

Option	Description
Delay Time	Time delay, in seconds, the instrument waits before taking a measurement at each step of an internal or user sweep. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 0
Meas Freq	Oscillator frequency range 100 Hz to 40 MHz. The 41941A/B impedance probe kit extends this to 100 MHz. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported. Default = 1 MHz
Integ Time	Instrument integration time: S (short), M (medium), or L (long). Default = S
Osc Level	Test signal level. Allowable voltage levels and resolutions are: Minimum = 10 mV; Maximum = 1V. Default = 10mV
Averages	Number of averages. Maximum = 256. Default = 1
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP 4271 1 MHz Digital Capacitance Meter

IC-CAP supports only external bias sources when performing measurements using the HP 4271. Both hardware and software calibrations are available. The instrument makes measurements in user sweep only. If the *CV_FREQ* system variable is defined, it must be set equal to 1 MHz before making a measurement with the HP 4271, otherwise an error is reported.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

The following table describes the HP 4271 options and their default values, where applicable.

Table 12 HP 4271 Options

Option	Description
Hold Time	Time the instrument waits before starting an internal or user sweep. Default = 0
Delay Time	Time, in seconds, the instrument waits before taking a measurement at each step of an internal or user sweep. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 0
Init Command	This is a command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP 4275 Multi-Frequency LCR Meter

The HP 4275 includes an optional internal DC bias source. IC-CAP checks for this internal bias source when you issue the *Rebuild* command in the Hardware Setup window. For the internal DC bias to be recognized, the *DC BIAS* selector switch must be set to Internal. Only hardware calibration is available and the instrument makes measurements in user sweep only.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

The test signal level on the HP 4275 can only be set manually with the *OSC LEVEL* dial and *MULTIPLIER* switches. This signal level must be set by the user to a reasonable value such as 10 mV to obtain accurate results, since a high signal level can

modulate the DC operating point. The *MULTIPLIER* is set to 1 when the instrument is powered up; a different setting must be selected manually.

When using the internal DC bias, the bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

The following table describes the HP 4275 options and their default values, where applicable.

Table 13 HP 4275 Options

Option	Description
Hold Time	Time the instrument waits before starting an internal or user sweep. Range is 0 to 650 seconds in 10 msec steps. Default = 0
Delay Time	Time the instrument waits before taking a measurement at each step of an internal or user sweep. Range is 3 msec to 650 sec. Resolution is in 1 msec steps for the 3 to 65 msec range; 10 msec for the 65.01 to 99.99 msec range; and, 100 msec for the 100 msec to 650 sec range. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 3 msec
Meas Freq	Measurement Frequencies. When the instrument is not equipped with option 004, it accepts frequency measurements at 10K, 20K, 40K, 100K, 200K, 400K, 1M, 2M, 4M, and 10M. When equipped with option 004, it accepts measurements at 10K, 30K, 50K, 100K, 300K, 500K, 1M, 3M, 5M, and 10M. Enter valid frequencies only. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported. Because the unit of *CV_FREQ* is Hz, divide it by 1K for this field. Default = 1 MHz
High Res	Enables or disables high resolution mode. Yes = enabled; No = disabled. Default = No

Table 13 HP 4275 Options (continued)

Option	Description
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP 4280 1 MHz Capacitance Meter

The HP 4280 measures the capacitance-voltage characteristics of semiconductor devices. The test signal of the instrument is a 1 MHz sine wave. The HP 4280 also contains a built-in DC bias source with an output capability of 0 to ±100V and a maximum setting resolution of 1 mV. Capacitance-voltage measurements can be taken using this internal voltage source or an external bias unit. The HP 4280 includes an internal calibration capability. Measurements can be made in either internal or user sweep. If the *CV_FREQ* system variable is defined, it must be set to 1 MHz before making a measurement with the HP 4280, otherwise an error is reported.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

When using the internal DC bias, this bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

The following table describes the HP 4280 options and their default values, where applicable.

Table 14 HP 4280 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use the instrument's internal sweep. Default = No

Table 14 HP 4280 Options (continued)

Option	Description
Hold Time	Time the instrument waits before starting internal or user sweep. Range is 0 to 650 seconds in 10 msec steps. Default = 3 msec
Delay Time	Time delay before each measurement is taken when using internal sweep. Range is 3 msec to 650 seconds. Resolution is in 1 msec steps for the 3 to 65 msec range, 10 msec for the 65.01 to 99.99 msec range, and 100 msec for the 100 msec to 650 second range. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 3 msec
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Meas Speed	Measuring speed: S (slow), M (medium), or F (fast). Default = S
Sig Level (10, 30)	Signal level: 10 or 30 mV rms. Default = 10
High Res	Enables or disables high resolution mode. Yes = enabled. No = disabled. Default = No
Conn Mode	Connection mode. When using the HP 4280 internal bias source, set to 10. When using an external bias source, connect the source to the EXT-SLOW connector on the HP 4280 rear panel and set the connection mode to 12. Default = 10
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP / Agilent 4284 Precision LCR Meter

The HP/Agilent 4284 is a general purpose LCR meter with a frequency range of 20 Hz to 1 MHz. The instrument includes an internal calibration. Options 001 and 006 are supported by IC-CAP. Option 001 includes a built-in internal bias source. Standard cable lengths are 0 and 1 meter; option 006 supports 2 and 4 meter lengths as well. Measurements can be made in user sweep mode only.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

When using the internal DC bias, the bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

CAUTION

Prior to configuring the HP/Agilent 4284 for the current measurement, the IC-CAP driver resets the 4284 to a known state by sending the *RST command. The default reset state (1V, 1KHz signal) may cause damage to certain devices between the time the $RST is requested and the time the requested signal level is set. To avoid this problem, you can define the reset state. See “Defining the Reset State” on page 65.

The following table describes the HP/Agilent 4284 options and their default values, where applicable.

Table 15 HP / Agilent 4284 Options

Option	Description
Hold Time	Time the instrument waits before starting an internal or user sweep. Range is 0 to 650 seconds in 10 msec steps. Default = 0

Table 15 HP/Agilent 4284 Options (continued)

Option	Description
Delay Time	Time the instrument waits before each sweep point is measured. The range is 0 to 60 seconds. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 0
Meas Freq	Measuring frequency. Only a set of frequencies are available. The range is 20 Hz to 1 MHz. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported. Default = 1 MHz
Integ Time	Instrument integration time: S (short), M (medium), or L (long). Default = M
Osc Level	Test signal level in volts or amps. Allowable voltage levels and resolutions are: Minimum = 5 mV Maximum = 20V with opt 001, 2V otherwise Between 5 mV and 200 mV: resolution = 1 mV Between 200 mV and 2V: resolution = 10 mV Between 2V and 20V: resolution = 100 mV (Opt. 001 only) Allowable current levels and resolutions are: Minimum level = 50 µA rms Maximum level = 200 mA rms with opt 001, 20 mA otherwise Between 50 µA and 2 mA: resolution = 10 µA Between 2 mA and 20 mA: resolution = 100 µA Between 20 mA and 200 mA: resolution = 1 mA (Opt. 001 only) The Instrument Options folder accepts test signal levels outside these ranges. However, if a measurement is attempted, an error message is issued and the measurement is not performed. Default = 10m
Osc Mode [V,I]	Specify V (voltage) or I (current). Automatic Level Control (ALC) is not supported. Default = V

Table 15 HP/Agilent 4284 Options (continued)

Option	Description
Averaging [1-256]	The averaging rate of the instrument. Default = 1
Cable Length	Cable length, in meters: 0, 1, 2, or 4. Default = 1M
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP/Agilent 4285 Precision LCR Meter

The HP/Agilent 4285 is a general purpose LCR meter with a frequency range of 75 kHz to 30 MHz. The instrument includes an internal calibration. Option 001, which adds a built-in internal bias source, is supported by IC-CAP. Measurements can be made in user sweep only.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

When using the internal DC bias, the bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

CAUTION

Prior to configuring the HP/Agilent 4285 for the current measurement, the IC-CAP driver resets the 4285 to a known state by sending the *RST command. The default reset state (1V, 1KHz signal) may cause damage to certain devices between the time the $RST is requested and the time the requested signal level is set. To avoid this problem, you can define the reset state. See “Defining the Reset State” on page 65.

The following table describes the HP/Agilent 4285 options and their default values, where applicable.

Table 16 HP/Agilent 4285 Options

Option	Description
Hold Time	Time the instrument waits before starting an internal or user sweep. Default = 0
Delay Time	Time the instrument waits before each sweep point is measured. Range is 0 to 60 seconds in 1 msec steps. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 0
Meas Freq	Measuring frequency. Range is 75 kHz to 30 MHz with 100 Hz resolution. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported. Default = 1 MHz
Integ Time	Instrument integration time: S (short), M (medium), or L (long). Default = M
Osc Level	Test signal level in volts or amps. The allowable voltage levels and resolutions are: Minimum level = 5 mV rms Maximum level = 2V rms Between 5 mV and 200 mV: resolution = 1 mV Between 200 mV and 2V: resolution = 10 mV The allowable current levels and resolutions are: Minimum level = 200 µA rms Maximum level = 20 mA rms Between 200 µA and 2 mA: resolution = 20 µA Between 2 mA and 20 mA: resolution = 200 µA The Instrument Options folder accepts test signal levels outside these ranges. However, if a measurement is attempted, an error message is issued and the measurement is not performed. Default = 10m

Table 16 HP/Agilent 4285 Options (continued)

Option	Description
Osc Mode [V,I]	Specify V (voltage) or I (current). Automatic Level Control (ALC) is not supported. Default = V
Averaging [1-256]	The averaging rate of the instrument. Default = 1
Cable Length	Cable length, in meters: 0, 1, or 2. Default = 1
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Agilent E4980A Precision LCR Meter

The Agilent E4980A is a general-purpose LCR meter. The Agilent E4980A is used for evaluating LCR components, materials, and semiconductor devices over a wide range of frequencies (20 Hz to 20 MHz) and test signal levels (0.1 mVrms to 2 Vrms, 50 µA to 20 mArms). With Option 001, the E4980A's test signal level range spans 0.1 mV to 20 Vrms, and 50 µA to 200 mArms. Also, the E4980A with Option 001 enables up to ±40 Vrms DC bias measurements (without Option 001, up to ±2 Vrms), DCR measurements, and DC source measurements using the internal voltage source.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

When using the internal DC bias, the bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

CAUTION

Prior to configuring the Agilent E4980A for the current measurement, the IC-CAP driver resets the E4980 to a known state by sending the *RST command. The default reset state (1V, 1KHz signal) may cause damage to certain devices between the time the $RST is requested and the time the requested signal level is set. To avoid this problem, you can define the reset state. See "Defining the Reset State" on page 65.

The following table describes the Agilent E4980A options and their default values, where applicable.

Table 17 Agilent E4980A Options

Option	Description
Hold Time	Time the instrument waits before starting an internal or user sweep. Range is 0 to 650 seconds in 10 msec steps. Default = 0
Delay Time	Time the instrument waits before each sweep point is measured. The range is 0 to 60 seconds. When biasing the device with an external DC source (e.g., an Agilent 4142B or 4156C), the DC source's delay/hold options override this option. Default = 0
Meas Freq	Measuring frequency. Only a set of frequencies are available. The range is 20 Hz to 1 MHz. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported. Default = 1 MHz
Integ Time	Instrument integration time: S (short), M (medium), or L (long). Default = M

Table 17 Agilent E4980A Options (continued)

Option	Description
Osc Level	Test signal level in volts or amps. Allowable voltage levels and resolutions are: Minimum = 0 mVrms Maximum = 20 Vrms with opt 001, 2Vrms otherwise Between 0 mVrms and 200 mVrms: resolution = 100 µVrms Between 200 mVrms and 500 mVrms: resolution = 200 µVrms Between 500mVrms and 1Vrms: resolution = 500 µVrms Between 1 Vrms and 2 Vrms: resolution = 1 mVrms Between 2 Vrms and 5 Vrms: resolution = 2 mVrms (Opt. 001 only) Between 5 Vrms and 10 Vrms: resolution = 5 mVrms (Opt. 001 only) Between 10 Vrms and 20 Vrms†: resolution = 10 mVrms (Opt. 001 only) † When the test frequency is more than 1 MHz, the maximum oscillator voltage level that can be set is 15 Vrms. Allowable current levels and resolutions are: Minimum level = 0 Arms Maximum level = 100 mArms with opt 001, 20 mA otherwise Between 0 µArms and 2 mArms: resolution = 1 µArms Between 2 mArms and 5 mArms: resolution = 2 µArms Between 5 mArms and 10 mArms: resolution = 5 µArms Between 10 µArms and 20 mArms: resolution = 10 µArms Between 20 mArms and 50 mArms: resolution = 20 µArms (Opt. 001 only) Between 50 mArms and 100 mArms: resolution = 50 µArms (Opt. 001 only) The Instrument Options folder accepts test signal levels outside these ranges. However, if a measurement is attempted, an error message is issued and the measurement is not performed. Default = 10m
Osc Mode [V,I]	Specify V (voltage) or I (current). Automatic Level Control (ALC) is not supported. Default = V

Table 17 Agilent E4980A Options (continued)

Option	Description
Averaging [1-256]	The averaging rate of the instrument. Default = 1
Cable Length	Cable length, in meters: 0, 1, 2, or 4. Default = 1M
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Agilent 4294A Precision Impedance Analyzer

The Agilent 4294A is a precision impedance analyzer designed to measure impedance (inductance, capacitance, and resistance) at frequencies between 40 Hz and 110 MHz. The instrument includes an internal calibration.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

When using the internal DC bias, the bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

Frequency cannot be swept using IC-CAP.

The following table describes the Agilent 4294A options and their default values, where applicable.

Table 18 Agilent 4294A Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use the instrument's internal sweep. Default = No.
Hold Time	Time the instrument waits before starting an internal or user sweep. Default = 0.
Delay Time	Time the instrument waits before each sweep point is measured. Range is 0 to 30 seconds. Resolution is 1 msec. Default = 0.
Meas Freq	Measuring frequency. Only a set of frequencies are available. Range is 40 Hz to 110 MHz. Resolution is 1 mHz at 40 Hz and 1 kHz at 110 MHz. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported. Default = 1 MHz.
Bandwidth	Measurement bandwidth. 1 FAST (fastest measurement), 2, 3, 4, 5 PRECISE (highest accuracy measurement). Default = 1.
Osc Level	Test signal level. Allowable voltage levels and resolutions are: minimum = 5 mV, maximum = 1 V. Default = 500 mV. Resolution = 1 mV.
Averages [1-256]	Point Averages, minimum 1, maximum = 256. Default = 1
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0.
Meas Range	Selects DC bias range. Three ranges: 1 mA, 10 mA, and 100 mA. Default = 1 mA.
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = no entry.

Agilent E4991A RF Impedance / Material Analyzer

The Agilent E4991A is an RF impedance/material analyzer designed to measure impedance (inductance, capacitance, and resistance) at frequencies between 1 MHz and 3 GHz. Measurements can be made in internal sweep mode only.

IC-CAP assigns the following name to this unit:

CM Capacitance Meter Unit

When using the internal DC bias, the bias unit is also included in the CM unit. Therefore, the unit name of this CM unit should also be entered in the *Unit* fields of both the voltage bias Input and the capacitance Output specifications of the Setup.

Frequency cannot be swept using IC-CAP.

The following table describes the Agilent E4991A options and their default values, where applicable.

Table 19 Agilent E4991A Options

Option	Description
Use User Sweep	Yes = use user sweep, No = use the instrument's internal sweep, default = No.
Hold Time	Time the instrument waits before starting an internal or user sweep, default = 0.
Delay Time	Time the instrument waits before each sweep point is measured. Range is 0 to 20 seconds, default = 0.
Meas Freq	Measuring frequency. Only a set of frequencies are available. Range is 1 MHz to 3 GHz with 1 kHz resolution. If the *CV_FREQ* system variable is defined, it must be set equal to this frequency, otherwise an error is reported, default = 1 MHz.
Osc Level	Test signal level in volts. Allowable voltage levels and resolutions are: minimum = 5 mV; maximum = 502 mV, default = 100 mV, resolution = 1 mV. The Instrument Options dialog accepts test signal levels outside these ranges. However, if a measurement is attempted, an error message is issued and the measurement is not performed.

Table 19 Agilent E4991A Options (continued)

Option	Description
Averages [1-100]	Point Averages, minimum = 1, maximum = 256, default = 1.
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example), use this option to avoid measurement timeouts. Default=0.
Bias Current Limit	Bias current limit, minimum 2 mA, maximum 50 mA, resolution 10 μA, default 2 mA.
Cal Reference Plane	Used to select the calibration reference plane, either Coaxial (C) or Fixture (F).
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = no entry.

Network Analyzers

A network analyzer is an integrated stimulus/response test system that measures the magnitude and phase characteristics of a 1-port or multi-port network by comparing the incident signal with the signal transmitted through the device or reflected from its inputs. A network analyzer provides a waveform with a specified attenuation and frequency as inputs to the network or device under test. It then measures the magnitude and the phase information of both the reflected and transmitted waves.

The network analyzers supported by IC-CAP are:

- Agilent E5071C ENA Series Network Analyzer
- Agilent PNA Series Vector Network Analyzer
- HP 3577 Network Analyzer
- HP/Agilent 8510 Network Analyzer
- HP/Agilent 8702 Network Analyzer
- HP/Agilent 8719 Network Analyzer
- HP/Agilent 8720 Network Analyzer
- HP/Agilent 8722 Network Analyzer
- HP/Agilent 8753 Network Analyzer
- Wiltron360 Network Analyzer

A network analyzer contains an S-parameter test set that allows automatic selection of S_{11}, S_{21}, S_{12}, and S_{22} measurements. S-parameters are used to quantify the signals involved in microwave design. S, for *scattering*, describes the act of an energy wave front entering, exiting, or reflecting off the 2-port network being characterized. Physically, the wave is an electromagnetic flow of energy, a traveling complex voltage wave. Mathematically, the S-parameter is a voltage normalized by the impedance of the environment so that its expression relates all information about voltage, current, and impedance at the same time.

The primary advantage of characterization with S-parameters is that they can be measured by terminating a network in its characteristic impedance instead of a short or open. The following figure mathematically illustrates how S-parameters are defined.

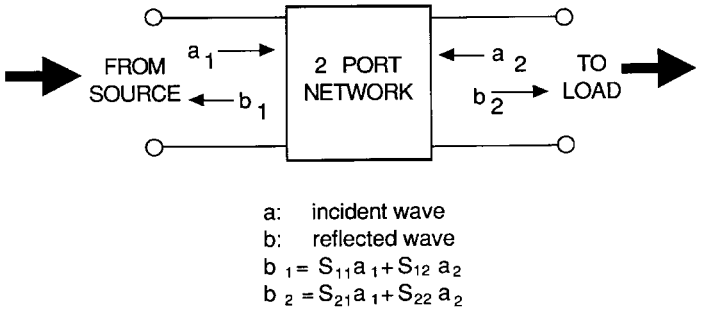

Figure 2 Mathematical Description of S-parameters

Referring to the previous figure, when a network port is terminated so that there is no reflected energy, it is said to be terminated in its characteristic impedance *Z0*. If at port 2, $a_2 = 0$ because b_2 looked into a Z0 load and was not reflected, then

$$b_1 = S_{11} \bullet a_1 + S_{12} \bullet 0 \qquad \text{or}$$

$$S_{11} = \left.\frac{b_1}{a_1}\right|_{a_2 = 0}$$

This defines an input reflection coefficient with the output terminated by a matched load (Z0). Similarly,

$$S_{22} = \left.\frac{b_2}{a_2}\right|_{a_1 = 0}$$

defines an output reflection coefficient with the input terminated by Z0.

$$S_{21} = \frac{b_2}{a_1}\bigg|_{a_2 = 0}$$

defines the forward transmission (insertion) gain with the output port terminated in Z0.

$$S_{12} = \frac{b_1}{a_2}\bigg|_{a_1 = 0}$$

defines the reverse transmission (insertion) gain with the input port terminated in Z0.

The following figure is a graphic description of how S-parameters are defined.

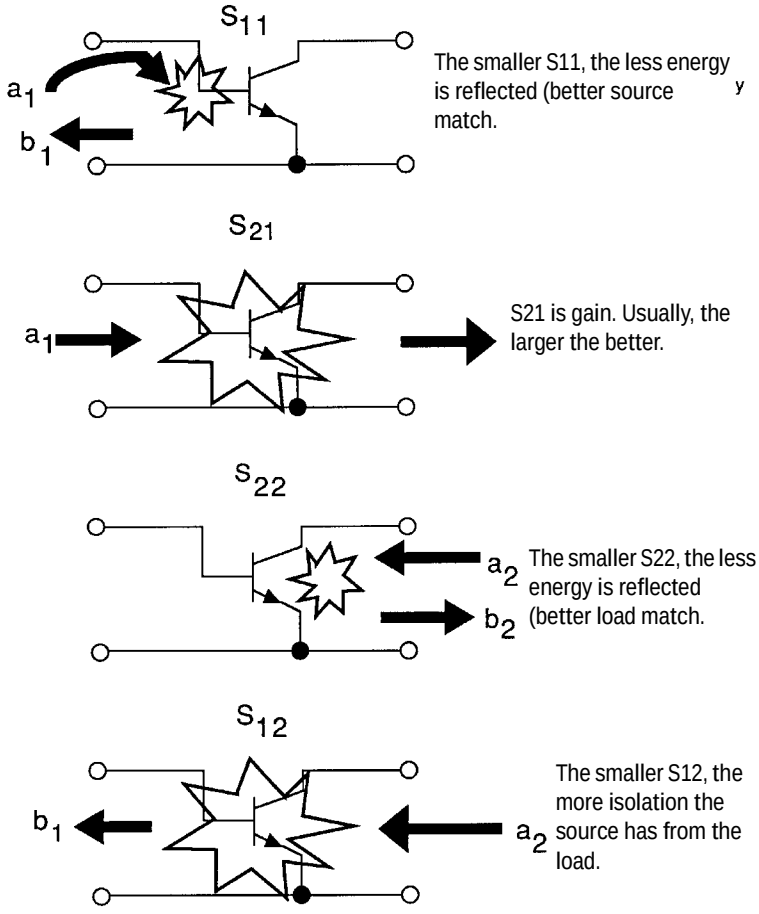

Figure 3 Graphic Description of S-parameters

NOTE

The error terms saved to file during a network analyzer software calibration are not identified by error code.

The order shown below represents the order in which they are saved and displayed in IC-CAP:

0. EDF [directivity]
1. EDR [directivity]
2. EXF [isolation]
3. EXR [isolation]
4. ESF [source match]
5. ERF [ref freq response]
6. ESR [source match]
7. ERR [ref freq response]
8. ELF [load match]
9. ETF [trans freq response]
10. ELR [load match]
11. ETR [trans freq response]

Agilent E5071C ENA Series Network Analyzer

IC-CAP supports the Agilent E5071C ENA Series RF network analyzer. The following table lists each analyzer and its frequency range:

Table 20 Supported ENA Series Network Analyzers

Instrument Name	Low Frequency	High Frequency
Agilent E5071C-240/440	9 kHz	4.5 GHz
Agilent E5071C-245/445	100 kHz	4.5 GHz
Agilent E5071C-280/480	9 kHz	8.5 GHz
Agilent E5071C-285/485	100 kHz	8.5 GHz

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

NOTE IC-CAP loads the Instrument Options parameters, including Source Power, Sweep Time, and so on, during an ENA measurement. Since this involves setting values critical to the calibration, an error or warning may be issued.

The ENA Series network analyzers are recognized when you issue the Rebuild, Measure, or Calibrate command.

This driver only supports Frequency mode with sweep types of Linear, List, Log, and Constant.

- Linear sweep mode allows you to specify the start/stop frequencies, number of points, and step size.
- List sweep mode allows you to sweep up to 202 individual frequencies.
- Log sweep mode allows you to specify start/stop frequencies, number of decades, and points per decade. The points are log spaced and you can specify a total of 202 points.
- Constant mode allows you to measure 1 individual frequency.

Table 21 on page 90 describes the E5071C ENA options and their default values, where applicable. For more information on options, refer to the E5071C ENA Series Network Analyzer Help file located in the analyzer.

A self-test function is not provided for this instrument.

Calibration

The IC-CAP Calibrate command loads Setup information into the ENA prior to calibrating. When running a measurement afterwards, the calibration set must match IC-CAP's Setup and it must be valid.

Only hardware calibration is supported. The calibration must be either manually executed or executed using dedicated calibration software and saved in a directory in the ENA. The calibration and state file must have extension *.sta*. To measure calibrated data, set the instrument option *Cal Type* to *H* (Hardware) and specify a file name with a *.sta* extension in the Instrument Option field *Cal/State File Name*.

On the ENA mainframe, the default directory for saving and reading calibration and state files is *D:\State*. You can save the calibration file in a different directory and still recall it from IC-CAP by setting the system variable *ENA_CAL_FILE_PATH* to the new directory (use full path such us *D:\my_dir*).

When running a measurement recalling a calibration set, the frequency sweep and the instrument options should be consistent with the calibration set. Warnings will be issued in the IC-CAP Status window when relevant ENA measurement settings (such as IF Bandwidth or Port Power) differ from the calibration settings.

NOTE

The *.sta* file type should be a save state file that includes the instrument state and the calibration data. So when saving the *.sta* file inside the instrument for further use, make sure to use the *State & Cal* save type in the Save/Recall menu.

The ENA has the capability to interpolate between points. Therefore, you can specify a different frequency range and number of points during a measurement as long as the measured frequency range is within the calibrated frequency range. However, be aware that a loss in accuracy occurs due to interpolation.

Table 21 Agilent E5071C ENA Options

Option	Description
Use User Sweep [Yes/No]	Yes = use user sweep. No = use instrument's internal sweep. Default = No
Hold Time (sec)	Time, in seconds, the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time (sec)	Time the instrument waits before setting each frequency in user sweep mode. Default = 0
Sweep Time (sec)	Time the instrument takes for each sweep. 0 = Auto Default = 0

Table 21 Agilent E5071C ENA Options (continued)

Option	Description
Sweep Type [SA]	S = Stepped mode. A = Analog (ramp) mode Default = S
Port Power Coupled [Yes/No]	Yes = Coupled mode. No = Non-Coupled mode. Default = Yes. When ports are coupled, the Port1 Src Power value is used for both Port 1 and 2. Port2 Src Power is ignored.
Port1 Src Power (dBm)	Defines the source Power for Port 1 and 2 when ports are coupled or the source power for Port 1 when ports are uncoupled. The power range depends on the ENA model and options.
Port2 Src Power (dBm)	Defines the source power for Port 2 when ports are uncoupled. This option field is ignored when ports are coupled. The power range depends on the ENA model and options.
Power Slope (db/GHz)	Can be any value between –2 and +2 dB/GHz Default = 0
IF Bandwidth (Hz)	Range 10 Hz to 500 kHz Nominal settings are: 10, 15, 20, 30, 40, 50, 70, 100, 150, 200, 300, 400, 500, 700, 1k, 1.5k, 2k, 3k, 4k, 5k, 7k, 10k, 15k, 20k, 30k, 40k, 50k, 70k, 100k, 150k, 200k, 300k, 400k, 500kHz Default = 1000 Hz Note: If a invalid value is specified, the ENA will not round it to the nearest available value. It will round up to the next higher value.
Avg Factor [1-1024]	Number of averages per measurement. [1-1024] Default = 1
Cal Type [HN]	H = Hardware calibration. N = No calibration Default = N
Cal/State File Name [.sta only]	Name of *.sta* file (with stored calibration and instrument state) to be used. Default = none

Table 21 Agilent E5071C ENA Options (continued)

Option	Description
Use ENA Calibration Settings [Yes/No]	This setting can be set to *Yes* only if a calibration file is available and Calibration Type is set to *H* (Hardware). Default = No When set to *Yes*, IC-CAP loads the calibration and runs the measurement without further initializing the instrument (i.e. without downloading the current Instrument Table settings). Although IC-CAP uses the calibration settings for measurements, it still sets the sweep settings (e.g. Start, Stop, Sweep Type, etc.). Therefore, make sure the requested sweep setting is consistent with the calibration settings as IC-CAP attempts to run the measurement without performing any frequency range checking. Also note that when this option is set to *Yes*, the driver responds as if *MEASURE_FAST*=Yes (i.e., calibration is loaded only when the measurement is first run or after errors or warnings occur).
Delay for timeouts (sec)	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default = 0
Init Command	Command field to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Technical Notes

- You can perform averaging by increasing the number of averages or decreasing the IF filter bandwidth. Both methods result in more samples taken at each frequency point. Decreasing the IF filter bandwidth not only increases the number of samples but also the time at each frequency point resulting in a longer sweep time. Increasing the number of averages, increases the number of sweeps. Although the driver supports both modes, using IF bandwidth for averaging is generally more efficient.

- Coupled ports have the same source power connected to Port 1 and Port 2 for forward and reverse S-parameter measurements.
- If you have significant insertion loss due to cables or bias networks, use power slope. Using the appropriate power slope can compensate for insertion loss as the frequency increases. However, if the network's return loss is too high, increasing the power slope will not compensate because the power is reflected back.
- Step sweep mode is more accurate than analog (ramp) mode, but analog mode is typically faster than step sweep mode. In step sweep mode, RF phase locking is performed at each frequency, which ensures that the frequency value is very accurate. This results in a longer transition time from 1 frequency point to the next and a longer total sweep time. In analog mode, the RF frequency is swept across the frequency range and its frequency accuracy depends on the linearity of the VCO (Voltage Controlled Oscillator).
- Sweep time is the total time to sweep from Start to Stop frequency. Several factors contribute to sweep time. For example at each point in step mode, sweep time is the summation of transient time due to phase locking, settling time, and measurement time, which depends on the IF Bandwidth filter. Although you can specify a sweep time, you should use auto mode (Sweep Time field = 0). This allows the ENA to determine the fastest sweep time based on the other settings. To view the actual sweep time, select Sweep Setup/Sweep Time on the ENA application's main window. For additional details on sweep time, see the E5071C ENA's online help.

Agilent PNA Series Vector Network Analyzer

IC-CAP supports the Agilent PNA Series vector network analyzers grouped as the Agilent PNA. The Table 22 lists each analyzer and its frequency range:

Table 22 Supported PNA Series Vector Network Analyzers

Instrument Name	Low Frequency	High Frequency
Agilent E8356A	300 kHz	3 GHz
Agilent E8357A	300 kHz	6 GHz
Agilent E8358A	300 kHz	9 GHz
Agilent E8361A	10 MHz	67 GHz
Agilent E8362A	45 MHz	20 GHz
Agilent E8362B	10 MHz	20 GHz
Agilent E8363A	45 MHz	40 GHz
Agilent E8363B	10 MHz	40 GHz
Agilent E8364A	45 MHz	50 GHz
Agilent E8364B	10 MHz	50 GHz
Agilent E8801A	300 kHz	3 GHz
Agilent E8802A	300 kHz	6 GHz
Agilent E8803A	300 kHz	9 GHz
Agilent N5250A	10 MHz	110 GHz

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

NOTE IC-CAP loads the Instrument Options parameters, including Source Power, Attenuation, and so on, during a PNA measurement. Since this involves setting values critical to the calibration, an error or warning may be issued.

The PNA Series network analyzers are recognized when you issue the Rebuild, Measure, or Calibrate command.

This driver only supports Frequency mode with sweep types of Linear, List, Log, and Constant.

- Linear sweep mode allows you to specify the start/stop frequencies, number of points, and step size.
- List sweep mode allows you to sweep up to 202 individual frequencies.
- Log sweep mode allows you to specify start/stop frequencies, number of decades and points per decade. The points are log spaced and you can specify a total of 202 points.
- Constant mode allows you to measure 1 individual frequency.

Table 23 describes the PNA options and their default values, where applicable. For more information on options, refer to the *PNA Series Network Analyzer Help* file located in the analyzer.

A self-test function is not provided for this instrument.

Calibration

The IC-CAP Calibrate command loads Setup information into the PNA prior to calibrating. When running a measurement afterwards, the calibration set must match IC-CAP's Setup and it must be valid.

Only hardware calibration is supported. The calibration must be either manually executed or executed using dedicated calibration software and saved in a directory in the PNA. The calibration file must have extension *.cst*.

NOTE

The *.cst* file type includes the instrument state and a pointer to the internal calset. The *.cst* file does not save the calibration coefficients (the internal calset). Do not delete the internal calset referenced by the *.cst* file otherwise the IC-CAP measurement will issue an error.

If you wish to save the calibration coefficients, save the active calset using a *.cal* file extension. If the internal calset is accidentally deleted, you can reinstate it by loading the *.cal* file from the front panel. Do this BEFORE running an IC-CAP measurement that uses the *.cst* file.

To measure calibrated data, set the instrument option Cal Type to H (Hardware) and specify a file name with a *.cst* extension in the Instrument Option field Cal/State File Name.

On the PNA mainframe, the default directory for saving and reading calibration and state file is C:\Program Files\Agilent\ Network Analyzer\Documents. You can save the calibration file in a different directory and still recall it from IC-CAP by setting the System Variable PNA_CAL_FILE_PATH to the new directory (use full path such us C:\my_dir\).

When running a measurement recalling a calibration set, the frequency sweep and the instrument options should be consistent with the calibration set. Warnings will be issued in the IC-CAP Status Window when relevant PNA measurement settings (such as IF Bandwidth or Port Power) differ from the calibration settings.

NOTE The PNA has the capability to interpolate between points. Therefore, you can specify a different frequency range and number of points during a measurement as long as the measured frequency range is within the calibrated frequency range. However, be aware that a loss in accuracy occurs due to interpolation.

Table 23 Agilent PNA Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use instrument's internal sweep. Default = No
Hold Time	Time, in seconds, the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time	Time the instrument waits before setting each frequency in user sweep mode. Default = 0
Sweep Time	Time the instrument takes for each sweep. 0 = Auto Default = 0
Sweep Type[SA]	S = Stepped mode. A = Analog (ramp) mode Default = S

Table 23 Agilent PNA Options (continued)

Option	Description
Port Power Coupled	Yes = Coupled mode. No = Non-Coupled mode. Default = Yes. When ports are coupled, the Port Src Power value is used for both Port 1 and 2. Port 2 Src Power is ignored. Attenuators are also coupled so that Port Src Atten is used for both ports and Port 2 Src Atten is ignored.
Port Src Power	Defines the source Power for Port 1 and 2 when ports are coupled or the source power for Port 1 when ports are uncoupled. The power range depends on the attenuator settings and the PNA model and options.
Port 2 Src Power	Defines the source power for Port 2 when ports are uncoupled. This option field is ignored when ports are coupled. The power range depends on the attenuator settings and the PNA model and options.
Port Atten Auto	Yes = Auto mode. No = Non-Auto mode. Default = No. When attenuators are in auto-mode, the PNA will set the most efficient values for the attenuators to obtain the requested output power at the port. In auto-mode, the full power range is directly available at the output port. In auto-mode, the instrument options Port Src Atten and Port 2 Src Atten are ignored.
Port Src Atten	Possible Values: 0, 10, 20, 30, 40, 50, 60, 70 dB Default = 0 The available range depends on the PNA model. For example, the E8364A attenuator range is 0-60 dB. This option is ignored when attenuators are in auto-mode.
Port 2 Src Atten	Possible Values: 0, 10, 20, 30, 40, 50, 60, 70 dB Default = 0 The available range depends on the PNA model. For example, the E8364A attenuator range is 0-60 dB. This option is ignored when attenuators are in auto-mode.
Power Slope	Can be any value between –2 and +2 dB/GHz Default = 0
Dwell Time	Sets the dwell time, in seconds, between each sweep point. Only available in Stepped sweep type. Default = 0 (Auto - PNA will minimize dwell time)

Table 23 Agilent PNA Options (continued)

Option	Description
IF Bandwidth	Possible Values: 1, 2, 3, 5, 7, 10, 15, 20, 30, 50, 70, 100, 150, 200, 300, 500, 700, 1k, 1.5k, 2k, 3k, 5k, 7k, 10k, 15k, 20k, 30k, 35k, 40k Default = 1000 Hz Note: If a invalid value is specified, the PNA will not round it to the nearest available value. It will round up to the next higher value.
Avg Factor	Number of averages per measurement. [1-1024] Default = 1
Cal Type[HN]	H = Hardware calibration. N = No calibration Default = N
Cal / State File Name	Name of .cst file (cal file and instrument state) to be used. Default = none
Use PNA Calibration Settings [Yes / No]	This setting can be set to *Yes* only if a calibration file is available and Calibration Type is set to *H* (Hardware). Default = No When set to *Yes*, IC-CAP loads the calibration and runs the measurement without further initializing the instrument (i.e., without downloading the current Instrument Table settings). Although IC-CAP uses the calibration settings for measurements, it still sets the sweep settings (e.g., Start, Stop, Sweep Type, e.t.c.). Therefore, make sure the requested sweep setting is consistent with the calibration settings as IC-CAP attempts to run the measurement without performing any frequency range checking. Also note that when this option is set to *Yes*, the driver responds as if *MEASURE_FAST*=Yes (i.e., calibration is loaded only when the measurement is first run or after errors or warnings occur).
Delay for timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default = 0

Table 23 Agilent PNA Options (continued)

Option	Description
Init Command	Command field to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Technical Notes

- You can perform averaging by increasing the number of averages or decreasing the IF filter bandwidth. Both methods result in more samples taken at each frequency point. Decreasing the IF filter bandwidth not only increases the number of samples but also the time at each frequency point resulting in a longer sweep time. Increasing the number of averages, increases the number of sweeps. Although the driver supports both modes, using IF bandwidth for averaging is generally more efficient.
- Coupled ports have the same source power connected to Port 1 and Port 2 for forward and reverse S-parameter measurements. In addition, the attenuator settings are coupled.
- When port attenuators are set to auto mode, the PNA automatically chooses the attenuator value that provides the requested power level at the output port. Accurate S-parameter calibration requires that the attenuator settings do not change during measurements or calibration, therefore auto mode is not recommended.
- If you have significant insertion loss due to cables or bias networks, use power slope. Using the appropriate power slope can compensate for insertion loss as the frequency increases. However, if the network's return loss is too high, increasing the power slope will not compensate because the power is reflected back.

- Step sweep mode is more accurate than analog (ramp) mode, but analog mode is typically faster than step sweep mode. In step sweep mode, RF phase locking is performed at each frequency, which ensures that the frequency value is very accurate. This results in a longer transition time from 1 frequency point to the next and a longer total sweep time. In analog mode, the RF frequency is swept across the frequency range and its frequency accuracy depends on the linearity of the VCO (Voltage Controlled Oscillator).
- Sweep time is the total time to sweep from Start to Stop frequency. Several factors contribute to sweep time. For example at each point in step mode, sweep time is the summation of transient time due to phase locking, settling time, dwell time, and measurement time, which depends on the IF Bandwidth filter. Although you can specify a sweep time, you should use auto mode (Sweep Time field = 0). This allows the PNA to determine the fastest sweep time based on the other settings. To view the actual sweep time, select Sweep/Sweep Time on the PNA application's main window. For additional details on sweep time, see the PNA's online help.
- Dwell time is the time spent at each frequency point before sampling starts. For most applications, you should set dwell time to auto mode. In auto mode, the PNA increases the dwell time as the sweep time increases to comply the total sweep time. If long delays are present in the circuit and additional settling time is needed, set the dwell time to an appropriate value.

  Dwell time is not active in analog mode—only in step mode. If the sweep time in analog mode is increased significantly (because of a setting), the PNA can internally switch to step mode and set an optimum value for the dwell time.

HP 3577 Network Analyzer

The HP 3577 has a frequency range of 5 Hz to 200 MHz (100 kHz to 200 MHz with HP 35677A/B S-Parameter Test Set). The RF source is an integral part of this instrument; DC bias levels must be supplied from external sources.

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

Because this instrument does not offer full 2-port calibration, IC-CAP provides a popular 12-term correction for this instrument that is widely used for 2-port measurements. Manual operation is required to measure standards interactively. Separate calibration data can be obtained for each Setup; the data is saved and retrieved when Setups are written to or read from files.

Though IC-CAP supports the HP 3577A and B models, the Discrete Sweep capability of HP 3577B is not available with IC-CAP. Therefore, the log and list frequency sweeps must be performed as a User Sweep.

For most 2-port AC measurements, the network analyzer units must be biased with a current or voltage source to supply DC power to the DUT. A DC analyzer can be used for this. Therefore, a typical S-parameter measurement Setup specification would use the unit name of the network analyzer unit (NWA) in the *Unit* field of the Output and the unit names of the DC analyzer units in the *Unit* fields of the biasing Inputs.

NOTE The HP 35677A/B S-Parameter Test Set has a maximum DC bias range of ±30V and ±20mA with some degradation of RF specifications; ±200mA damage level.

The measurement methods, listed in the following table, are selected by setting the *Use User Sweep* and *Use Fast CW* flags in the HP 3577 Instrument Options folder.

Table 24 HP 3577 Measurement Modes

Mode	Description
Slow CW Sweep Mode	*Use User Sweep* = Yes. *Use Fast CW* = No The instrument sets each frequency then measures all 4 S-Parameters. Although somewhat slow, this method has the advantage of gathering all of the parameters for a frequency at approximately the same time.

Table 24 HP 3577 Measurement Modes (continued)

Mode	Description
Fast CW Sweep Mode	*Use User Sweep* = Yes. *Use Fast CW* = Yes This mode is faster than *Slow CW Sweep* because it performs just 2 user sweeps. The instrument first measures the forward parameters (S_{11} and S_{21}), then changes the test set direction and measures the reverse parameters (S_{12} and S_{22}).
Single Freq CW Mode	*Use User Sweep* = Yes. *Use Fast CW* = No The instrument performs a spot frequency measurement. Except for the number of frequencies, this mode is the same as the *Slow CW Sweep Mode*.
Internal Sweep Mode	*Use User Sweep* = No Fastest available sweep type. Sweep must be linear. Values for start, stop, and number of points are stored in the instrument. The number of points in the linear sweep must match 1 of the HP 3577's allowed *number of points* choices. When IC-CAP is unable to fit an internal sweep, it attempts to use the *Fast CW Mode*.

The following table describes the HP 3577 options and their default values, where applicable. For more information on options, refer to the *HP 3577 Operating and Programming Manual.*

Table 25 HP 3577 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use instrument's internal sweep. Default = No
Hold Time	Time, in seconds, the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time	Time the instrument waits before setting each frequency in user sweep mode. Default = 100 msec
Input A Attn	Sets Input A attenuation. Choices are 0 or 20 dB. Default = 20 dB

Table 25 HP 3577 Options (continued)

Option	Description
Input B Attn	Sets Input B attenuation. Choices are 0 or 20 dB. Default = 20 dB
Input R Attn	Sets Input R attenuation: 0 or 20 dB. Default = 20 dB
Source Power	Source signal level. Range is –45 to 15 dBm. Default = –10 dBm
Sweep Time [.05 - 16]	Instrument internal sweep time, in seconds. Default = 100 msec.
IF Bandwidth	Instrument receiver resolution, in Hz. Default = 1000 Hz
Use Fast CW	Enables *Fast CW* mode. Default = Yes
Avg Factor [1-256]	Number of averages per measurement. Default = 1
Cal Type[SN]	S = Software calibration. N = No calibration. Default = S
Soft Cal Sequence	Software calibration requires measurement of (L)oad, (O)pen, (S)hort, (T)hru, and optionally (I)solation in a certain order. This string defines the sequence of these standard measurements by these letters (L, O, S, T, I). Default = LOST
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

The system variables used by the 12-term software calibration are listed in the following table. They primarily affect S_{11} and S_{22} corrections at high frequencies. Load and Short standards are assumed ideal in the calibration frequency range. These variables can be defined at Setup or higher levels.

Table 26 System variables

Variable	Description
CAL_OPEN_C0 CAL_OPEN_C1 CAL_OPEN_C2	Define a capacitance of an Open standard in Farads. This value applied to port 1 and port 2. A second-order polynomial is assumed for its frequency response. Copen = C0 + C1 • F + C2 • F^2. Default = 0 (for C0, C1, and C2)
TWOPORT_Z0	Defines impedance of port 1 and port 2, in Ohms. This and the open capacitance value are used to calculate open gamma correction data. Also used by *TwoPort* function. Default = 50 Ohms

Note: *CAL_OPEN_C* is replaced by *CAL_OPEN_C0; CAL_Z0* is replaced by *TWOPORT_Z0*. Use the new variables when possible; the old variables are effective for the software calibration when the new variables are undefined.

HP / Agilent 8510 Network Analyzer

The HP/Agilent 8510 is identical to the HP 8753 except:

- The 8510A has a frequency range of 45 MHz to 26.5 GHz.
- The 8510B options can source frequencies up to 100 GHz.
- The RF source is a separate external instrument.
- The 8510A does not support frequency list mode—it cannot run internal log and list sweeps.

IC-CAP assumes an *A* model if the instrument is manually added to the Instrument List (in the Hardware Setup window) by selecting it and clicking the Add button. For IC-CAP to recognize a newer model, use the *Rebuild* command or perform a dummy measurement: use a linear sweep with the *Use Linear List* option set to *No*. Note that the 8510C is treated as the *B* model.

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

NOTE

IC-CAP loads the Instrument Options parameters, including Source Power, Attenuation, and so on, during an 8510 measurement. Because this involves setting values critical to the calibration, the following warning may be issued: Calibration may be invalid.

If the IC-CAP Calibrate command is used to load Setup information to the 8510 prior to calibrating, the calibration set must match IC-CAP's Setup and be valid.

For information on the processes listed below, refer to the section, "HP 3577 Network Analyzer" on page 100.

- Use of DC bias sources
- Available measurement modes
- System variables used in software calibration

NOTE

Use the 12-term software calibration carefully at very high frequencies where accuracy of the Load termination generally degrades.

The following table describes the 8510 options and their default values, where applicable. For more information on options, refer to the *HP 8510 Operating and Programming Manual*.

Table 27 HP/Agilent 8510 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use instrument's internal sweep. Default = Yes
Hold Time	Time, in seconds, the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time	Time the instrument waits before setting each frequency in user sweep mode. Default = 100 msec
Port 1 Attn	Sets Port 1 attenuation. This option is ignored by the 8510XF. Range is 0 to 90 dB. Default = 20 dB

Table 27 HP/Agilent 8510 Options (continued)

Option	Description
Port 2 Attn	Sets Port 2 attenuation. This option is ignored by the 8510XF. Range is 0 to 90 dB. Default = 20 dB
Source Power	Range is –90 to 30 dbm. Default = –10 dBm
Power Slope	Range is 0 to 1.5 dbm/GHz. Default = 0
Fast Sweep (Ramp)	Enables ramp sweep. Default = No
Sweep Time [.05 - 100]	Instrument sweep time. Default = 100 msec
Use Fast CW	Enables *Fast CW* mode. Default = Yes
Trim Sweep	Adjusts frequency at each band edge. Default = 0
Avg Factor [1-4096]	Number of averages per measurement. Default = 1
Cal Type[SHN]	S = Software calibration. H = Hardware calibration. N = No calibration. Default = H
Cal Set No. [1-8]	Specifies an instrument calibration set. Default = 1
Soft Cal Sequence	Software calibration requires measurement of (L)oad, (O)pen, (S)hort, (T)hru, and optionally (I)solation in a certain order. This string defines the sequence of these standard measurements by these letters (L, O, S, T, I). Default = LOST
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Use Linear List	Yes = load linear sweeps into the 8510's frequency list instead of 1 of the fixed point counts. (Not available on 8510A.) Default = Yes
Init Command	Command field to set the instrument to a mode not supported by the option table. Command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

When performing 2 sequential CW measurements that use different CW cal subsets, the 8510 may report the error RF UNLOCKED. A system variable is available in IC-CAP, in the *Measurement Options* group, to ignore this error:

IGNORE_8510_RF_UNLOCK

When defined as Yes, IC-CAP ignores a temporary and benign RF UNLOCKED error from the 8510.

Making Measurements with Uncoupled Ports

To calibrate using the 8510XF driver:

1. Set input sweeps and instrument options. To set port 1 power, set Source Power. To set port 1 power slope, set Power Slope. Set averaging. Ignore the Port 1 and 2 Attenuators fields as the 8510XF does not have attenuators.
2. In the Init Command field, type the following command string to set port 2 power and slope:
   `PPCOUPLEOFF;POWP2 <power>SLPP2ON <slope>`

   Example:
   `PPCOUPLEOFF;POWP2 -20;SLPP2ON 0.05;`

   sets P2=-20 dB and Power slope 2 to 0.05 dB/GHz
3. Click Calibrate. This downloads the sweep settings, the instrument option settings, and sets the 8510XF with uncoupled ports.
4. Perform RF Calibration and save the results in one of the Calsets.

When making a measurement using the 8510XF driver, the driver recalls the calibration data and the setting used during calibration. If you want to use the same power level and slope, you do not need to make any changes. If you want to change the port 2 power setting, use the Init Command field as in step 2 (you do not need PPCOUPLEOFF since the ports are already off when calibration is recalled). Be aware that the 8510XF will issue a warning if you set a different port power for the measurements.

HP / Agilent 8702 Network Analyzer

The HP/Agilent 8702 network analyzer has a frequency range of 300 kHz to 3 GHz (IC-CAP does not support the lightwave analyzer features). Use Option 006 and turn on the frequency doubler from the front panel if 6 GHz is desired. The RF source is an integral part of this instrument. For other features, refer to the section, *"HP/Agilent 8753 Network Analyzer"* on page 112 because the HP/Agilent 8702 is almost identical to the HP/Agilent 8753 in the E/E mode. IC-CAP supports both HP/Agilent 85046A and HP/Agilent 85047A S-Parameter Test Sets for the HP/Agilent 8702.

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

For most 2-port AC measurements, the network analyzer units must be biased with a current or voltage source to supply DC power to the DUT. A DC analyzer can be used to supply this current or voltage source. Therefore, a typical S-parameter measurement Setup specification would use the unit name of the network analyzer unit (NWA) in the *Unit* field of the Output and the unit names of the DC analyzer units in the *Unit* fields of the biasing Inputs.

For information on the topics listed below, refer to the section, "HP/Agilent 8753 Network Analyzer" on page 112.

- Measurement modes
- Options

NOTE The 8702 occupies 2 GPIB addresses, the instrument itself and the display. The display address is derived from the instrument address by complementing the least significant bit. Hence, if the instrument is at an even address, the display occupies the next higher address; if the instrument is at an odd address, the display occupies the next lower address.

HP / Agilent 8719 Network Analyzer

The HP/Agilent 8719 is identical to the HP/Agilent 8720 except the 8719 has a frequency range of 50 MHz to 13.5 GHz. For information, refer to the next section, "HP/Agilent 8720 Network Analyzer."

HP / Agilent 8720 Network Analyzer

The HP/Agilent 8720 network analyzer has a frequency range of 50 MHz to 20 GHz. The RF source and S-parameter test set are an integral part of this instrument. IC-CAP supports the HP/Agilent 8720 A, B, C, and D models. (The 8720 D is the only model that supports uncoupled port power.)

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

NOTE The 8720 occupies 2 GPIB addresses, the instrument itself and the display. The display address is derived from the instrument address by complementing the least significant bit. Hence, if the instrument is at an even address, the display occupies the next higher address; if the instrument is at an odd address, the display occupies the next lower address.

For most 2-port AC measurements, the network analyzer units must be biased with a current or voltage source to supply DC power to the DUT. A DC analyzer can be used to supply this current or voltage source. Therefore, a typical S-parameter measurement Setup specification would use the unit name of the network analyzer unit (NWA) in the *Unit* field of the Output and the unit names of the DC analyzer units in the *Unit* fields of the biasing Inputs.

Measurement modes for the 8720 are the same as for the 8753; refer to Table 29 for this information.

For system variables used in the software calibration, refer to Table 26 in the HP 3577 section.

The following table describes the 8720 options and their default values, where applicable.

Table 28 HP/Agilent 8720 Options

Option	Description
Use User Sweep	Yes = use user sweep. No = use instrument's internal sweep Default = No
Hold Time	Time, in seconds, that the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time	Time the instrument waits before setting each frequency. Default = 100 msec
Port 1 Source Power	Range is –65 to 10 dBm. Default = –10.00 dBm
Port 1 Power Range	Specifies which instrument power range to use. Range is 1 to 12 for models A, B, and C; range is 0 to 11 for model D. (The Hardware calibration is turned off by the instrument when calibrated Power Range and requested Power Range don't match.) Default = 1
Port 1 Auto Power Range†	Enables auto power ranging on port 1. Default = Yes
Coupled Port Power†	Enables/disables coupled test port power. When disabled, Port 2 options are ignored. Default = Yes
Port 2 Source Power†	Range is –65 to 10 dBm. Default = –10.00
Port 2 Power Range†	Specifies which instrument power range to use. Range is 1 to 12 for models A, B, and C; range is 0 to 11 for model D. (The Hardware calibration is turned off by the instrument when calibrated Power Range and requested Power Range don't match.) Default = 1
Port 2 Auto Power Range†	Enables auto power ranging on port 2. Default = Yes
Sweep Time	Instrument sweep time. A zero sweep time turns on the Auto Sweep Time, which ensures the minimum sweep time. Default = 100 msec

Table 28 HP/Agilent 8720 Options (continued)

Option	Description
IF Bandwidth (Avg)	Instrument's receiver IF bandwidth. Default = 1000 Hz
Use Fast CW	Enables *Fast CW* mode. Default = Yes
Avg Factor [1-999]	Number of averages per measurement. Default = 1
Cal Type[SHN]	S = Software calibration. H = Hardware calibration. N = No calibration. Default = H
Cal Set No.	Models A, B, and C: 1 through 5 specifies which instrument calibration sets to use; 6 specifies the active instrument state. Model D: 1 through 32 specifies which instrument calibration sets to use; 33 specifies the active instrument state. Default = 1
Soft Cal Sequence	Software calibration requires measurement of (L)oad, (O)pen, (S)hort, (T)hru, and optionally (I)solation in a certain order. This string defines the sequence of these standard measurements by these letters (L, O, S, T, I). Default = LOST
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Use Linear List	Yes = load linear sweeps into the HP/Agilent 8720's frequency list instead of one of the fixed point counts. This mode should be faster than using the instruments linear frequency sweep. Default = Yes
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

† These options apply only when using built-in test set (Model D).

HP / Agilent 8722 Network Analyzer

The HP/Agilent 8722 is identical to the HP/Agilent 8720 except for its frequency range—the HP/Agilent 8722 has a frequency range of 50 MHz to 40 GHz.

HP / Agilent 8753 Network Analyzer

The HP/Agilent 8753 network analyzer has a frequency range of 300 kHz to 3 GHz (6 GHz with Option 006). The instrument contains an RF source for frequency sweeps, but DC bias must be supplied from external sources to acquire biased RF data.

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

IC-CAP supports the HP/Agilent 8753 A, B, C, D, E, and D opt 011 models (D models must be firmware revision 6.14 or higher). The standard D and E models have a built-in test set; the A, B, C, and D opt 011 models are used in conjunction with an external test set. IC-CAP supports both the HP/Agilent 85046A and HP/Agilent 85047A S-Parameter Test Sets.

NOTE IC-CAP cannot differentiate between model D and D opt 011. When using the 8753D with an external test set, alias it as an 8753C in the *instraliases* file in the *$ICCAP_ROOT/iccap/lib* directory.

NOTE The 8753 occupies 2 GPIB addresses, the instrument itself and the display. The display address is derived from the instrument address by complementing the least significant bit. Hence, if the instrument is at an even address, the display occupies the next higher address; if the instrument is at an odd address, the display occupies the next lower address.

The model is recognized when you issue the *Rebuild*, *Measure*, or *Calibrate* command. If you manually add the instrument to the active instrument list (by clicking the *Add* button), IC-CAP assumes the instrument is an A model until one of the previously described commands is issued.

NOTE

Some early models of the 8753C (ROM 4.00 and 4.01) have GPIB problems that prevent IC-CAP from finding this instrument during *Rebuild*. Add the instrument manually after PRESET when IC-CAP ignores this instrument. The model is recognized when *Measure* or *Calibrate* is performed.

A self-test function is not provided for this instrument.

For most 2-port AC measurements, the network analyzer units must be biased with a current or voltage source to supply DC power to the DUT. A DC analyzer can be used to supply this current or voltage source. Therefore, a typical S-parameter measurement Setup specification would use the unit name of the network analyzer unit (NWA) in the Unit field of the Output and the unit names of the DC analyzer units in the Unit fields of the biasing Inputs.

Hardware calibration is only supported when using *Internal Sweep* mode or *Single Freq CW* mode. For measurement modes that do not support internal instrument calibration, software calibration is provided. When software calibration is set in the instrument options, use the *Calibrate* command to initiate the calibration. IC-CAP will load the frequency values and options into the instrument and then direct you to connect the various calibration standards required to perform the calibration.

The *Calibrate* command can also be used to download the desired instrument state when requesting a hardware calibration You must then calibrate the instrument manually (refer to the instrument manual) and store the results in one of the instrument's state registers. With this method there is no need to manually input the instrument state to match the IC-CAP settings.

The measurement modes listed in Table 29 are selected by setting a combination of the following fields (details follow) in the 8753 Instrument Options folder:

- Use User Sweep
- Use Fast CW
- Use Linear List
- Cal Type field

IC-CAP contains routines that compare its sweep values with those stored in the 8753. In case of discrepancies, IC-CAP prompts you to specify whether the sweeps should be modified to match the instrument. This may not be practical when variables are included in the sweep specifications.

Error checking ensures a valid measurement mode. When discrepancies are found, the following changes are made:

- For CON frequency, *Use User Sweep* is set to Yes and *Use Fast CW* is set to No.
- For internally calibrated sweeps, *Use User Sweep* is set to No.
- When frequency is not the main sweep, *Use Fast CW* is set to No, *Cal Type* is set to N, and *Use User Sweep* is set to Yes.

Refer to "HP 3577 Network Analyzer" on page 100 for system variables used in the software calibration.

Table 30 describes the 8753 options and their default values, where applicable. Differences in options when using the 8753 with an external test set versus a built-in test set are noted.

For optimum performance of the HP/Agilent 85047 test set, 6 GHz mode requires Source Power to be +20dBm. The Instrument Options folder should show *20* as the Source Power level when the Freq Range is 6 GHz. Setting Source Power to less than 20 can cause *No IF Found* errors in the 8753. Further information on the power requirements for 6 GHz operation can be found in the instrument's operation manual.

When the test set switches between 3 and 6 GHz operation, the 8753 automatically changes Source Power level.

- 3 to 6 GHz Switching: 20 dBm.
- 6 to 3 GHz Switching: 0 dBm.

When Hardware calibration is used, a specified calibration set recalls the original calibration power level. When Software or no calibration is used, the Source Power will be forced to one of the default levels if the test set has to switch modes. When a Source Power level other than the above forced values is required, perform one of the following:

- Make a dummy measurement first to switch the test set to the desired frequency mode
- Manually switch the test set to the desired frequency mode
- Use the *Calibrate* command to download the desired instrument state

NOTE

The 8753 may not reflect the power level specified in the Instrument Options folder if the analyzer is in HOLD mode. When the 8753 is in HOLD mode and receives a remote command to switch the frequency mode of the test set, it postpones switching modes until an actual measurement sweep is triggered. When the *Measure* or *Calibrate* command is issued, IC-CAP initializes the state before triggering a measurement. Thus IC-CAP will download the power level specified in the Instrument Options folder and the analyzer will force it to its default value when the measurement is triggered.

For descriptions of the variables used in software calibration, refer to Table 26 in the *HP 3577 Network Analyzer* section.

Table 29 Supported Measurement Modes

Mode	Description	Use User Sweep	Use Fast CW	Use Linear List	Cal Type
Slow CW Sweep	IC-CAP performs a spot measurement of 2-port data by setting the instrument to each frequency point individually and measuring all 4 S-parameters. Although slow, this method has the advantage of gathering all of the parameters for a frequency at approximately the same time. Only uncalibrated data can be obtained from this type of measurement since each frequency point is measured in CW mode. Typically used when frequency is not the primary sweep (Sweep Order ≠ 1).	Yes	No	Ignored	S, N
Fast CW Sweep	Similar to *Slow CW Sweep*, this mode is faster because it first measures the forward parameters (S_{11} and S_{21}) with a single sweep, then the reverse parameters (S_{12} and S_{22}). This is accomplished by using the dual channel feature of the instrument. As with *Slow CW Sweep*, instrument calibration is not possible and only uncalibrated data can be obtained.	Yes	Yes	Ignored	S, N
Single Freq CW	This is the only user sweep mode capable of acquiring 2-port data using hardware calibration. A CW mode calibration can be performed and saved in one of the state registers to be recalled when a measurement is executed.	Yes	No	Ignored	H,S, N

Table 29 Supported Measurement Modes (continued)

Mode	Description	Use User Sweep	Use Fast CW	Use Linear List	Cal Type
Internal Sweep	Fastest available sweep type. Sweeps can be linear, log, or list. † Since this is an internal sweep, hardware calibration is possible. IC-CAP expects that the calibration over the appropriate frequencies has been completed before the measurement is performed.	No	No	Yes or No	H,S, N

Notes:

† For linear sweeps, the number of points requested must fit one of the 8753's predefined *number of points*. If the desired number of points is not one of the legal set values, IC-CAP checks to see if it still can make a valid measurement by increasing the number of points on the instrument such that data at the desired frequencies can be acquired. For example, a 300 to 500 kHz sweep in 6 steps internally requires IC-CAP to set the instrument to 11 points because 11 is a legal value. When IC- CAP is unable to fit an internal sweep, it attempts to use the Fast CW mode. If CW mode is not desired, set *Use Linear List* = *Yes*.

For log and list sweeps, set *Use Linear List* = *Yes*. This uses the instrument's frequency list capability. Because the 8753 is limited to thirty sub-sweeps, it can store no more than sixty frequencies.

Instrument options must match those for which the 8753 was calibrated.

Table 30 Options for the HP / Agilent 8753

Option	Description
Use User Sweep	Yes = use user sweep. No = use instrument's internal sweep Default = No
Hold Time	Time, in seconds, the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time	Time the instrument waits before setting each frequency. Default = 100 msec
Port 1 Atten†	Sets Port 1 attenuation. Range is 0 to 70 dB. Default = 20 dB

Table 30 Options for the HP/Agilent 8753 (continued)

Option	Description
Port 2 Atten†	Sets Port 2 attenuation. Range is 0 to 70 dB. Default = 20 dB
Source Power†	Range is –10 to 25 dbm. Default = –10
Power Slope	Models A, B, C, and D opt 11: Range is 0 to 2 dbm/GHz. Default = 0 Models D and E: Range is –2 to +2dBm/GHz. Default = 0 dBm/GHz
Port 1 Source Power††	Sets Port 1 source power level. Range is –85 to +10 dBm. Default = –10 dBm
Port 1 Power Range[0-7]††	Sets Port 1 source power range. The valid range is 0 to 7. Default = 0
Port 1 Auto Power Range††	Enables auto power ranging on port 1. Default = No
Coupled Port Power††	Enables/disables coupled test port power. When disabled, Port 2 options are ignored. Default = Yes
Port 2 Source Power††	Sets Port 2 source power level. Range is –85 to +10 dBm. Default = –10 dBm
Port 2 Power Range[0-7]††	Sets Port 2 source power range. The valid range is 0 to 7. Default = 0
Port 2 Auto Power Range††	Enables auto power ranging on port 2. Default = No
Sweep Time	Instrument sweep time. Zero sweep time turns on the Auto Sweep Time, which ensures the minimum sweep time. Default = 100 msec
IF Bandwidth (Avg)	Instrument receiver IF bandwidth setting in the Averaging menu. Default = 1000 Hz
Use Fast CW	Enables Fast CW mode. Default = Yes
Avg Factor [1-999]	Number of averages per measurement. Default = 1
Cal Type [SHN]	S = Software calibration. H = Hardware calibration. N = No calibration. Default = H

Table 30 Options for the HP / Agilent 8753 (continued)

Option	Description
Cal Set No.	Models A, B, C, and D opt 11: 1 through 5 specifies which instrument calibration sets to use; 6 specifies the active instrument state. Models D and E: 1 through 32 specifies which instrument calibration sets to use; 33 specifies the active instrument state. Default = 1
Soft Cal Sequence	Software calibration requires measurement of (L)oad, (O)pen, (S)hort, (T)hru, and optionally (I)solation in a certain order. This string defines the sequence of these standard measurements by these letters (L, O, S, T, I). Default = LOST
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Use Linear List	Yes = load linear sweeps into the 8753 frequency list instead of one of the fixed point counts. This mode should be faster than using the instrument's linear frequency sweep. Default = Yes
Freq Range [36N]†	This option sets Frequency Range to 3 GHz, 6 GHz, or No change. Default = N
Init Command	This command field sets the instrument to a mode that is not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Notes:
† These options apply only when using external test set (Models A, B, C, and D opt 11).
†† These options apply only when using built-in test set (Models D and E).

Wiltron360 Network Analyzer

The Wiltron360 network analyzer has a frequency range of 10 MHz to 60 GHz depending on the RF source. If the frequency sweep requested exceeds the limits of the source, IC-CAP issues an error message, *Parameter Out of Range. Check Inputs*. The RF source is an integral component of the system for frequency sweeps, but DC bias must be supplied from external sources to acquire biased RF data.

The Wiltron360 can be added to the active instrument list by issuing the *Rebuild* command from the Hardware Setup window. If the Wiltron360 is manually added to the active instrument list using the *Add* button, IC-CAP verifies that the instrument is available on the bus when either the *Measure* or *Calibrate* command is first issued.

IC-CAP assigns the following name to this unit:

NWA Network Analyzer Unit

IC-CAP supports only hardware calibration for this instrument. After a broadband calibration, the 360 can perform a *spot* measurement of swept calibrated data—software calibration is not required. This capability also allows a CON frequency input defined in an IC-CAP setup to be used with a broadband calibration. For either measurement method, the requested frequency points must be a subset of the frequency sweep currently set up on the instrument. If the requested frequency point is not part of the instrument sweep, IC-CAP will issue an error message.

The measurement modes listed in Table 31 are selected by setting the following fields in the Wiltron360 Instrument Options folder:

- Use User Sweep
- CW Mode Setup
- Cal Type

IC-CAP supports recalling calibration sets from the Wiltron360 internal disk drive. The *Cal File Name* option is provided to recall the desired calibration state from disk. If no calibration file name is supplied, the current active instrument state is used.

IC-CAP loads the Instrument Options parameters during a measurement. Because this involves setting stimulus values sensitive to the calibration, instrument options must match those for which the Wiltron360 was calibrated; otherwise, the Wiltron360 will issue a *Calibration may be invalid* message if any of the downloaded stimulus values are different from the current calibration. If this message is displayed, check the Instrument Options folder to verify which value is different and modify as appropriate. Use the *Calibrate* command from the Setup menu to download the options information to the Wiltron360 prior to calibrating. This ensures that the calibration will match IC-CAP's Setup and be valid.

Table 31 Measurement Modes

Mode	Description	Use User Sweep	CW Mode Setup	Cal Type
CW Sweep	Used when frequency is not the primary sweep (Sweep Order = 1). IC-CAP performs a spot measurement of 2-port data by setting the instrument to each frequency point individually and measuring all S-parameters. A broadband hardware calibration can be performed. The calibration does not have to match the IC-CAP sweep exactly; however, the desired swept frequency points must be a subset of the calibrated frequencies.	Yes	No	H or N
Single Freq CW	Used when a CW mode hardware calibration is performed.	Yes	Yes	H

Table 31 Measurement Modes

Mode	Description	Use User Sweep	CW Mode Setup	Cal Type
Internal Sweep	Linear, log, or list sweeps. Hardware calibration over requested frequencies is completed before an IC-CAP measurement is performed. Unlike *CW Sweep*, the calibration frequencies must match the setup.	No	No	H or N

The following table describes the Wiltron360 options and their default values, where applicable.

Table 32 Wiltron360 options

Option	Description
Use User Sweep	Yes = Use user sweep No = use instrument's internal sweep. Default = No
Hold Time	Time, in seconds, the instrument waits before each sweep to allow for DC settling. Default = 0
Delay Time	Time the instrument waits before setting each frequency in user sweep mode. Default = 50 msec
Port 1 Src Atten	Sets Port 1 source attenuation. Range is 0 to 70 dB, in 10 dB increments. Default = 0 dB
Port 2 Src Atten	Sets Port 2 source attenuation. Range is 0 to 70 dB, in 10 dB increments. Default = 0 dB
Port 2 Test Atten	Sets test port attenuation (port 2). Range is 0 to 40 dB, in 10 dB increments. Default = 0 dB
Source Power	Range is dependent on test set used. Default = 0 dBm
IF Bandwidth [NRM]	Sets instrument's receiver IF Bandwidth. N = Normal R = Reduced M = Minimum. Default = N
Avg Factor [1-4095]	Sets number of averages per measurement Default = 1
Use CW Mode Setup	Indicates to IC-CAP that NWA has been set up in single point (CW) measurement mode. Default = No

Table 32 Wiltron360 options (continued)

Option	Description
Cal Type[HN]	H = Hardware calibration N = No calibration Default = H
Cal File Name	Specifies instrument calibration file to recall. If hardware calibration is requested and this option is empty, IC-CAP will use the current active instrument state. Default = Null
Soft Cal Sequence	Software calibration requires measurement of (L)oad, (O)pen, (S)hort, (T)hru, and optionally (I)solation in a certain order. This string defines the sequence of these standard measurements by these letters (L, O, S, T, I). Default = LOST
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none
System Variables	None. Software calibration is not provided for the Wiltron360.

Oscilloscopes

The oscilloscopes supported by IC-CAP are:

- HP 54120T Series Digitizing Oscilloscopes
- HP 54510 Digitizing Oscilloscope
- Agilent Infiniium Oscilloscope
- HP 54750 Series Digitizing Oscilloscopes

HP 54120T Series Digitizing Oscilloscopes

The HP 54120 Series of digitizing oscilloscopes measure time-domain responses, including TDR (time-domain reflectometry).

- HP 54121T measures signals from DC through 20 GHz.
- HP 54122T (does not have a step generator and cannot perform TDR measurements) provides programmable input attenuation. Bandwidth is reduced to 12.4 GHz due to the input attenuators.
- HP 54123T operates up to 34 GHz; it operates up to 20 GHz on channel 1 (the channel on which the step generator is available).

IC-CAP assigns the following names to the units:

CHn Channel Unit n (1, 2, 3, and 4)

A Setup configured for measurements using an HP 54120 Series is in the model file *54120.demo.mdl*. See Appendix G, “54120 Demo” for additional information about this demonstration file. These files also include examples using an HP 54120 Series oscilloscope with an HP 8130 pulse generator and provides hints for obtaining good alignment between measured and simulated waveforms when a pulse generator is used.

The following instrument capabilities are supported by IC-CAP:

- Time-domain measurements nested within DC bias settings provided by DC SMUs.
- 4-channel concurrent data acquisition.

- Offset, range, and probe attenuation adjustment for each channel. HP 54122T includes options to set internal attenuation for each channel (refer to Table 33).
- Averaging of between 1 and 2048 waveform acquisitions on each channel.
- Automatic Pulse Parameter Measurements, such as risetime and peak-to-peak voltage. These are requested in Outputs of *Mode* T. For help on the available choices, click the middle mouse button over the *Pulse Param* field and see the Status window.
- Square-wave generation (except HP 54122T) on CH1, the left-most connector on the test set. Frequency can be adjusted from 15.3 Hz to 500 kHz. To activate the step generator, the Setup should include an Input with *Mode* V and *Type* TDR. In the absence of a type TDR Input, the step generator is not activated.

The instruments do not support some of the fields present in a TDR Input. For example, it is not possible for the instrument to offer other than a 50-ohm source impedance. The one field that is of consequence to oscilloscope measurements is *Period*. IC-CAP directs the instrument to use the closest value supported.

The other TDR Input fields are ignored during measurement, and the following hardware-imposed values of the instrument's step function apply:

- Initial value of 0V
- Pulsed value of 200 mV into 50 ohms; 400 mV into an open-circuit
- Delay of approximately 17 nsec
- Risetime of approximately 40 psec
- Pulse width equal to about 50 percent of the specified period
- Source impedance of 50 ohms
- Time-Domain Reflectometry (except HP 54122T). When a type *TDR* Input is present in the Setup, the reflected signal is available on the unit designated CH1.

To make a time-domain measurement, a Setup must have these inputs and outputs:

- An Input with *Mode* T and *Type* LIN. Here, the values of *Start, Stop,* and *Number of Points* govern the time axis of the measurement. *Start* and *Stop* values define the time viewing window, and are relative to the trigger event used by the oscilloscope.
- Optionally, an Input of *Mode* V and *Type* TDR or PULSE. The *Period* field in this Input controls the rate of the oscilloscope's internal square-wave generator. If *Period* is set to 0, or if this Input is absent from the Setup, the oscilloscope's internal square-wave generator is not activated for the measurement. In this case, a trigger signal must be provided on the oscilloscope's trigger input.

  If the Input's *Unit* field is set to ground, IC-CAP ignores the Input during the measurement. In this manner, measurements can be performed using a pulse generator controlled by its front panel. If the Input's *Unit* field is set to the pulse unit of a supported pulse generator (for example, PULSE1 for an HP 8130 generator), then IC-CAP will control the pulse generator to provide stimulus to the DUT and oscilloscope.

  Refer to the HP 8130 Pulse Generator documentation provided with IC-CAP.
- To capture a waveform from any of the instrument's 4 channels requires an Output of *Mode* V. The Output Editor permits you to specify from which channel a waveform is desired. Define an Output for each channel of interest.
- To obtain automatically extracted pulse parameters at any of the 4 channels requires an Output of *Mode* T.

  The following pulse parameters can be requested: DUTYCYCLE, FALLTIME, FREQ, OVERSHOOT, PERIOD, PRESHOOT, RISETIME, VPP, VRMS, +WIDTH, and -WIDTH. Consult the instrument's *Front Panel Operation Reference* for definitions of these parameters or information on the process by which the instrument computes them.

By defining multiple Outputs for a scope channel, it is possible to obtain both the full time-domain waveform and any number of automatically extracted pulse parameters for that channel, all in the same measurement. This can be done with any or all of the 4 channels within the same measurement.

The following table describes the HP 54120 series options and their default values, where applicable.

Table 33 HP 54120 Series Options

Option	Description
Hold Time	Time, in seconds, prior to performing time-domain measurement. Can be used to permit additional DC stabilization when a time-domain sweep is nested within DC steps provided by a DC bias unit. Default = 0
Averages	Number of averages. Maximum = 2048. Default = 1
CH1 Offset†	DC offset value of Channel 1 in volts. Does not directly affect waveforms returned from the oscilloscope. However, an improper setting can cause the instrument to fail when measuring pulse parameters, such as RISETIME. Set to a value close to the middle of the expected range of the output voltage waveform to maximize the instrument's ability to achieve high resolution without experiencing clipping. Valid range is ± 500mV · (CH1 Probe Attn) · (CH1 Internal Attn). Default = 200.0mV
CH1 Probe Attn†	Set to 10 if the channel 1 probe provides a divide by 10 functionality (20dB). Specifying the attenuation of the probe permits the oscilloscope to generate data in which the probe attenuation is corrected out. Values between 1 and 1000 are accepted. Default = 1.0
CH1 Internal Attn†	HP 54122T only. This option causes IC-CAP to control attenuators inside the 54122 test set. The attenuators have limited power-handling ability††. Measured voltages will take the attenuation setting into account. Values 1, 3, 10, and 30 are valid. Default = 1.0

Table 33 HP 54120 Series Options (continued)

Option	Description
CH1 Range†	Set in excess of the maximum anticipated signal swing for this channel. Does not affect waveforms returned from the oscilloscope. However, an improper setting can cause the instrument to fail when measuring pulse parameters, such as RISETIME. Specify a *Range* value between
CH1 Range† (cont'd)	8mV · (CH1 Probe Attn) · (CH1 Internal Attn) and 640mV · (CH1 Probe Attn) · (CH1 Internal Attn). Default = 640.0 mV

Notes:
† Option table entries are also provided for *Offset, Probe Attn, Internal Attn,* and *Range* on channels CH2, CH3, and CH4.
††Changing the *Probe Attn* options for CH1-CH4 and the trigger input does not attenuate the input signals. It only changes the results reported by the instrument. To deliver signals exceeding 2V DC or 16 dBm AC peak, use an external attenuator.

By using the internal attenuators of the HP 54122T (via the Internal Attn options), larger voltages can be accepted. Limitations on attenuator voltage and power handling are described in the *Internal Atten* documentation in the *Channels Menu* chapter of the *HP 54122T Front Panel Reference*.

NOTE The external trigger is ignored if a TDR type Input is defined in the Setup. In the presence of a TDR type Input, the scope is triggered by its internal TDR step generator.

The TRG options listed in the following table apply when driving the trigger input of the oscilloscope with an external signal. This is typically done with the trigger output from a signal generator.

Table 34 Trigger Options for the HP 54120T Series

Option	Description
TRG Probe Attn	Set to 10 if the trigger probe is fitted with a 10X (20dB) divider. Values between 1 and 1000 are accepted. Default = 1.0

Table 34 Trigger Options for the HP 54120T Series (continued)

Option	Description
TRG Slope	Specify triggering on a rising (+) or falling (–) edge. Default = +
TRG Level	Voltage threshold at which triggering occurs. Valid range is ±1V · (TRG Probe Attn). Default = 100.0mV
Normalize TDR	If *Yes*, TDR waveform data from CH1 is subject to the HP 54120 series reflection normalization process. This can substantially improve waveform integrity when cabling and test fixtures have impedance mismatches. Prior to using this option perform calibration of the network reflection path via the front panel *Network* page. Default = No (This option is not supported by the HP 54122.)
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example) use this option to avoid measurement timeouts. Default=0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP 54510 Digitizing Oscilloscope

The HP 54510 is a 1 giga-sample/second, 2-channel digitizing oscilloscope. The HP 54510 driver is an example of a driver created using the *Open Measurement Interface*. The driver's source code can be found in the files *user_meas3.hxx* and *user_meas3.cxx* in the directory *$ICCAP_ROOT/src*. For information, refer to Chapter 2, "Drivers."

IC-CAP assigns the following names to the units:

CHn Channel Unit n (1 and 2)

The following instrument capabilities are supported by IC-CAP:

- Time-domain measurements nested within DC bias settings provided by DC SMUs.
- 2-channel concurrent data acquisition.

- Offset, range, and probe attenuation adjustment for each channel. (Refer to Table 35.)
- Averaging 1 to 2048 waveform acquisitions on each channel.
- Automatic Pulse Parameter Measurements, such as risetime and peak-to-peak voltage. These are requested in Outputs of *Mode* T. For help on the available choices, click the middle mouse button over the *Pulse Param* field and see the Status window.

To make a time-domain measurement, a Setup must contain these Inputs and Outputs:

- An Input with *Mode* T and *Type* LIN. Here, the values of *Start, Stop,* and *Number of Points* govern the time axis of the measurement. *Start* and *Stop* values define the time viewing window, and are relative to the trigger event used by the oscilloscope. The HP 54510 driver uses the repetitive sampling mode and therefore always measures 501 points. The timebase range is set to 500 × step size of the input sweep. The timebase requires a value in the sequence 1-2-5, that is, 1 nsec, 2 nsec, 5 nsec, 10 nsec, ... , 1 sec, 2 sec, or 5 sec. If the Input step size does not correspond to a valid timebase, the driver aborts the measurement and recommends new stop and step values for the input sweep.
- Optionally, an Input of *Mode* V and *Type* PULSE. A trigger signal must be provided on the oscilloscope's trigger input. If the Input *Unit* field is set to ground, IC-CAP ignores the Input during the measurement. In this manner, you may perform measurements using a pulse generator controlled by its front panel. If the Input *Unit* field is set to the pulse unit of a supported pulse generator (for example, PULSE1 for an HP 8130 generator), then IC-CAP will control the pulse generator to provide stimulus to the DUT and oscilloscope. For more information, refer to "HP 8130 Pulse Generator" on page 147. Also refer to the documentation for the HP 54120 in the *54120.demo.mdl* file as well as Appendix G, "54120 Demo."
- To capture a waveform from either of the instrument's 2 channels requires an Output of *Mode* V. The Output Editor permits you to specify from which channel a waveform is desired. Define one such Output for each channel of interest.

- To obtain automatically extracted pulse parameters at either of the 2 channels, the Setup must include an Output of *Mode* T.

  The following pulse parameters can be requested: DUTYCYCLE, FALLTIME, FREQ, OVERSHOOT, PERIOD, PRESHOOT, RISETIME, VPP, VRMS, +WIDTH, and -WIDTH. Consult the instrument's *Front Panel Operation Reference* for definitions of these parameters, or information on the process by which the instrument computes them.

  By defining multiple Outputs for a scope channel, both the full time-domain waveform and any number of automatically extracted pulse parameters for that channel can be obtained, all in the same measurement. This can be done with either or both of the channels in the same measurement.

The following table describes the HP 54510 options and default values, where applicable.

Table 35 HP 54510 Options

Option	Description
Hold Time	Time, in seconds, prior to performing time-domain measurement. Can be used to permit additional DC stabilization when a time-domain sweep is nested within DC steps provided by a DC bias unit. Default = 0.0
Averages	Number of averages. Maximum = 2048. The HP 54510 rounds the number of averages to the nearest power of 2. If the value is exactly halfway between, it takes the higher value. Default = 1
CH1 Offset†	DC offset value of Channel 1, in volts. This does not directly affect waveforms returned from the oscilloscope. However, an improper setting can cause the instrument to fail when measuring pulse parameters, such as RISETIME. Set this to a value close to the middle of the expected range of the output voltage waveform; this will maximize the instrument's ability to achieve high resolution without experiencing clipping. Valid range is ±250V • (CH1 Probe Attn). Default = 0.0

Table 35 HP 54510 Options (continued)

Option	Description
CH1 Probe Attn†, ††	Set to 10 if the Channel 1 probe provides a divide by 10 functionality (20 dB) and 50 ohm input impedance is selected. Specifying the attenuation of the probe permits the oscilloscope to generate data in which the probe attenuation is corrected out. Values between 0.9 and 1000 are accepted. Default = 1.0
CH1 Range†	Set in excess of the maximum anticipated signal swing for this channel. This option does not affect waveforms returned from the oscilloscope. However, an improper setting can cause the instrument to fail when measuring pulse parameters, such as RISETIME. Default = 2.0

Notes:
† Option table entries are also provided for *Offset*, *Probe Attn,* and *Range* for CH2.
††Changing *Probe Attn* options for CH1, CH2 and the External Trigger input does not attenuate the input signals. It only changes the results reported by the instrument. To deliver signals exceeding 5V rms (50 ohm) or 250V (1 Mohm), an external attenuator should be used.

Refer to the following table for oscilloscope trigger options. The TRG/TRIG options apply to the trigger input. This is typically done with the trigger output from a signal generator. When using the EXT TRIG channel, be sure the *TRG Source* option is set to “E” (*External Trigger*).

NOTE

Instrument settings not included in the Instrument Options folder, such as input impedance, can be set manually before executing Measure.

Table 36 Oscilloscope Trigger Options for the HP 54510

Option	Description
EXT TRIG Attn	Attenuation of the EXT TRIG channel. Set to 10 if the trigger probe is fitted with a 10X (20dB) divider and the EXT TRIG channel is set to 50 ohms. Values between 0.9 and 1000 are accepted. Default = 1.0
TRG Source	Specify the trigger source channel: *1* (CH1), *2* (CH2) or *E* (External Trigger). Default = E
TRG Slope	Specify + (rising edge) or – (falling edge). Default = +
TRG Level	Voltage threshold at which triggering occurs. Valid range is ±2V • (TRG Probe Attn) for the EXT TRIG channel and ±1.5 • (full scale from center of screen) for channels CH1 and CH2. Default = 0.0
Delay for Timeouts	For long-running measurements (that use a high number of averages, for example), use this option to avoid measurement timeouts. Default = 0.0
Init Command	Use to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Agilent Infiniium Oscilloscope

The Agilent Infiniium scopes are available as 2 or 4-channel digitizing oscilloscopes. IC-CAP supports the following Infiniium scopes:

- 54810A, 54815A, 54820A, 54825A 500 MHz bandwidth, 1 GSa/s sample rate and 32K of memory width.
- 54835A, 1 GHz bandwidth, 4 GSa/s sample rate, 62K memory width.
- 54845A, 1.5 GHz bandwidth, 8 GSa/s sample rate, 64K memory width.

The IC-CAP driver supports acquisition only from Channels 1 and 2.

IC-CAP assigns the following names to the units:

CHn Channel Unit n (1 and 2)

The following instrument capabilities are supported by IC-CAP:

- Time-domain measurements nested within DC bias settings provided by DC SMUs.
- 2-channel concurrent data acquisition (Channel 1 and 2 only).
- Offset, range, and probe attenuation adjustment for each channel. (Refer to Table 37.)
- Averaging 1 to 2048 waveform acquisitions on each channel.
- Automatic Pulse Parameter Measurements, such as risetime and peak-to-peak voltage. These are requested in Outputs of *Mode* T. For help on the available choices, click the middle mouse button over the *Pulse Param* field and see the Status window.

To make a time-domain measurement, a Setup must contain these Inputs and Outputs:

- An Input with *Mode* T and *Type* LIN. Here, the values of *Start, Stop,* and *Number of Points* govern the time axis of the measurement. *Start* and *Stop* values define the time viewing window, and are relative to the trigger event used by the oscilloscope. The Infiniium acquisition range is given by the number of acquisition points multiplied by the sampling period (1/Acquisition Rate). Acquisition points and frequency are set in the instrument option table. If the time viewing window set by the Start and Stop values is wider than the acquisition range, the driver aborts the measurement. The Acquisition rate must be in the 1, 2.5, 5, 10 sequence, that is, 1MSa/s, 2.5 MSa/s, 5 MSa/s, etc. The maximum acquisition rate depends on the scope model. The acquisition mode may be Real or Equivalent Time. Real time mode usually is used for single events, such as transients, while equivalent time may be used for periodic signals.

- Optionally, an Input of *Mode* V and *Type* PULSE. A trigger signal must be provided on the oscilloscope's trigger input. If the Input *Unit* field is set to ground, IC-CAP ignores the Input during the measurement. In this manner, you may perform measurements using a pulse generator controlled by its front panel. If the Input *Unit* field is set to the pulse unit of a supported pulse generator (for example, PULSE1 for an HP 8130 generator), then IC-CAP will control the pulse generator to provide stimulus to the DUT and oscilloscope. For more information, refer to "HP 8130 Pulse Generator" on page 147.
- To capture a waveform from either of the instrument's 2 channels requires an Output of *Mode* V. The Output Editor permits you to specify from which channel a waveform is desired. Define one such Output for each channel of interest. When acquisition range and points differ from sweep time interval and points, the waveform is actually interpolated by the actual measured data. It is a good practice to use an acquisition range that is slightly greater than the time window, but not too much greater.
- To obtain automatically extracted pulse parameters at either of the 2 channels, the Setup must include an Output of *Mode* T.

The following pulse parameters can be requested: DUTYCYCLE, FALLTIME, FREQ, OVERSHOOT, PERIOD, PRESHOOT, RISETIME, VPP, VRMS, +WIDTH, and -WIDTH. Consult the instrument's *Front Panel Operation Reference* for definitions of these parameters, or information on the process by which the instrument computes them.

By defining multiple Outputs for a scope channel, both the full time-domain waveform and any number of automatically extracted pulse parameters for that channel can be obtained, all in the same measurement. This can be done with either or both of the channels in the same measurement.

As shown in the following instrument options table, the trigger source may be set to Channel 1 or 2, or to EXT or AUX. The trigger sweep may be Auto, Triggered or Single. Trigger level and slope are also specified.

The following table describes the Infiniium options and default values, where applicable.

Table 37 Infiniium Options

Option	Description
Hold Time	Time, in seconds, prior to performing time-domain measurement. Can be used to permit additional DC stabilization when a time-domain sweep is nested within DC steps provided by a DC bias unit. Default = 0.0
Sample Rate	The internal sample frequency. It must be in the 1, 2.5, 5, 10 sequence. In real-time mode the maximum sample rate is 1 GSa for the 54810A/15A, 2GSa for the 54820A/25A, 4 GSa for the 54835A and 8 GSa for the 54845A (2 channel mode). Default = 1 GSa.
Acquisition Mode	Can be real time (R) or equivalent time (E). Real time is used for single events such as transients while equivalent time may be used to increase the "equivalent" sampling rate when the waveform is periodical. Default = R.
Acquisition Count	Turns averaging on or off, and (when on) sets the number of averages. Allowed range is 1 through 4096. Use 1 to turn averaging off. Use 2 through 4096 to turn on averaging and set the count. Default = 1.
Acquisition Points	Number of acquired points at the sample rate. The acquisition range is defined as the acquisition period 1/(Sample rate) multiplied by the number of points. The number of points is limited by the memory depth: 32,768 points for the 54810A/15A/20A/25A and 65,536 points for the 54835A/45A.
CH1 Scale† [V/div.]	DC vertical sensitivity in Volts per division. When probe attenuation is 1 maximum sensitivity is 5 V/div. Minimum sensitivity is 1 mV/div for 54810A/15A/20A/25A and 2 mV/div for 54835A and 54845A. Default = 500 mV/div.
CH1 Offset† [V]	DC available offset. It depends on the scale. Maximum offset is ±250V when CHn Scale = 5 V/div.
CH1 Input†	Channel input impedance: DC 50 ohm (DC50),1 Mohm (DC), AC. LFR1 and LFR2 are also possible when using the Agilent 1153A differential probe. Default is DC.

Table 37 Infiniium Options (continued)

Option	Description
CH1 Probe Attn[†] [††]	Set to 10 if the Channel 1 probe provides a divide-by-10 functionality (20 dB) and 50 ohm input impedance is selected. Specifying the attenuation of the probe permits the oscilloscope to generate data in which the probe attenuation is corrected out. Values between 0.9 and 1000 are accepted. Default = 10.0.
Trigger Input	Set trigger input source (1, 2, AUX or EXT). Default is 1 for Channel 1.
Trigger Sweep	Set trigger sweep Modes to Auto (A), Triggered (T), or Single (S). Default is Auto (A).
Trigger Slope	The only supported trigger mode is Edge. Trigger slope may be positive (+) or negative (-). Default is positive (+).
Trigger Level [V]	Sets voltage level at which trigger occurs. Level range depends on sweep mode and scope type. Default is 500 mV.
Delay for Timeouts	For long-running measurements, such as collecting a high number of averages, use this option to avoid measurement timeouts. Default = 0.0
Init Command	Sets the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Notes:
[†] Option table entries are also provided for *Scale*, *Offset*, *Input* and *Probe Attn*, for CH2.
[††]Changing *Probe Attn* options for CH1, CH2 and the External Trigger input does not attenuate the input signals. It only changes the results reported by the instrument. To deliver signals exceeding 5V rms (50 ohm) or 250V (1 Mohm), an external attenuator should be used.

HP 54750 Series Digitizing Oscilloscopes

The IC-CAP driver for the HP 54750 supports the following plug-in modules:

- HP 54753A. This module is a 2-channel vertical plug-in with a TDR step generator built into channel one. The bandwidth of the TDR/vertical channel is 18 GHz. The bandwidth of channel 2 is 20 GHz.
- HP/Agilent 54754A. This module has 2 independent vertical channels and 2 independent step generators. The bandwidth of both channels is 18 GHz.
- HP 54752A and HP 54752B. The 54752A has two 50 GHz bandwidth channels and 54752B provides a single cost-effective channel.
- HP 54751A. This module has two 20 GHz bandwidth channels.

Since the instrument is configurable, the insertion of the instrument in the active instrument table *must* be done using rebuild active list. Plug-in modules *must* be placed starting from slot 1 without discontinuities. IC-CAP assigns the following names to the units:

- TDRn for TDR channels
- CHn for normal scope acquisition channels

Example files: A Setup configured for measurements using the HP 54750, is in the model file */examples/model_files/misc/hp54750.mdl*.

The following instrument capabilities are supported by IC-CAP:

- Time domain acquisition for each channel (TDR or CH).
- Offset, Scale, and Probe Attenuation adjustment for each channel.
- Averaging of between 1 and 4096 waveform acquisition.
- Automatic Pulsed/Waveform parameter measurements for each TDR or CH type channel.
- Trigger Probe Attenuation, Slope, Level, Mode as well as the trigger slot (2 or 4 in case 2 plug-ins are present) can be set in the instrument table.

- Start time, Stop time, and number of points are set in the Input Time sweep.
- Step generator on TDR channels. Frequency rate can be adjusted between 50 and 250 kHz. To activate the step generator the setup should include an Input with mode V and Type TDR. Note that only one TDR step generator can be active per setup (differential TDR is not supported). The period on the TDR input is used to calculate frequency for TDR/TDT measurements.
- TDR normalized measurements are supported for each of the TDR channels. To acquire a normalized TDR response, perform either software or hardware calibration, then set Normalize to *Y* in the TDR channel and measure. To perform software TDR calibration, first set the normalization option to *TDR*, then run Calibrate and follow the steps.
- TDT normalized measurements are supported for each plug-in. Plug-in channel 1 must be the TDR source, and channel 2 must be the TDT sink. To acquire a normalized TDT measurement on channel 2, perform either software or hardware TDT calibration, then set Normalize to *Y* on channel 2 (sink) and measure. To perform software TDT, set the normalization option to TDT, run Calibrate, and follow the steps.

You must be sure to insert the oscilloscope into IC-CAP's instrument table. Connect the instrument, switch it on, and perform Rebuild in the Hardware Setup. The HP 54750 should be now present in the Instrument List. Select *HP 54750* in the list and select Configure. The units should reflect the hardware configuration and the plug-in type in the Unit Table. Here are examples of what should appear in the table:

- If module HP/Agilent 54754 occupies slots 1 and 2, *TDR1* and *TDR2* units should appear in the Unit Table.
- If module HP 54753 occupies slots 1 and 2, *TDR1* and *CH2* units should appear in the Unit Table.

To make time-domain measurements (acquisition only), a setup must contain these Inputs and Outputs:

- An Input with Mode T, and Type LIN. Minimum start time is 20 nsec; max start time is 10 sec. The minimum time range is 100 psec while the maximum range is 10 sec. During acquisition (no internal TDR) the number of acquired points can be set to any number between 16 and 4096.
- A trigger signal must be provided at the trigger input (slot 2 or 4) to acquire any waveform. Trigger Mode can be selected in the instrument option. Use trigger mode FREErun or TRIGgered for periodic waveforms. Use option TRIGgered when using external trigger for example for acquiring transients or when using external TDR step generator.
- To capture a waveform, an Output of Mode V is required. Define an output for each channel of interest.
- To obtain automatically-extracted pulse parameters, the setup must include an output of mode T that specifies the unit and the requested parameter. Examples of parameter values are *VPP* and *VRMS*.

To make TDR or TDT measurements, a setup must contain these Inputs and Outputs:

- An Input with Mode T and Type LIN. Minimum start time is 20 nsec, max start time is 10 sec. The minimum time range is 100 psec while the maximum range is 10 sec. When the instrument's Normalize option is turned OFF, the number of acquired points can be set to any number between 16 and 4096. When the Normalize option is ON, the number of points can be set to any number between 16 and 4096 that is a multiple of 2, such as 512 or 1024.
- An Input with Mode V and Sweep Type TDR. The unit is set to the TDR source channel. Only the value of the Period is used during measurement for setting the frequency of the internal step generator. Use a value between 50 Hz (20 msec) and 250 kHz (4 usec). The other fields, such as Delay and Width, are used only by the simulator. If an external TDR step generator is used, then Unit must be set to GND, and all parameters (including Period) are used only by the simulator.

- To capture the output waveforms, insert 1 or 2 Outputs of mode V referring to the TDR source channel for TDR measurements, or to the sink channel for TDT measurements.
- (Optional). To measure waveform parameters such as VPP and RISETIME, insert 1 or more Outputs of mode T.

TDR or TDT measurements can be done with or without normalization. Normalization establishes a reference plane different from the oscilloscope output. The reflection and ohm measurements are based on the actual measured step height. Also, from this information, the scope builds a filter, which can be applied to any reflected signal. The risetime of the filtered step can be selected. The filtered step removes any losses or discontinuities from the reference plane generated by the plug-in.

To measure without normalization, simply set the Normalize flag to *N* in the instrument options for any channel involved in the TDR or TDT measurement.

To make normalized TDR measurements, either hardware or software normalization must be performed prior to measurement. To perform software calibration, set the Normalization mode to TDR in the Instrument Option Table. Then run Calibrate. This routine will load current sweeps (start, stop and period) in the instruments and then will ask the operator to insert the calibration standards (short and load) at the reference plane.

Once the instrument has been successfully calibrated, set the Normalize flag of the TDR source channel to 'Y' before running a measurement to acquire normalized data. Set the normalized response Unit to VOLT (default), REF or OHM in the Instrument Options Table. When setting response scale to VOLT, IC-CAP will acquire the actual normalized response. When the response scale is OHM, IC-CAP will acquire the normalized-to-50 ohm response. This is particularly useful when evaluating characteristic impedance of different line series. Setting the scale to REF will acquire the reflection due to a change of impedance. The normalized rise time can also be set in the instrument option table. The minimum settable rise time

actually depends on the number of points. Generally speaking, increasing the number of points allows a smaller rise time and therefore improves the space resolution (minimum distance between 2 discontinuities to distinguish them in the space/time domain).

To make normalized TDT measurements, either hardware or software normalization must be performed prior to measurement. To perform software calibration, set Normalization mode to TDT in the Instrument Option Table. Then connect source and sink together (without DUT) and run Calibrate.

Once the instrument has been successfully calibrated, set the Normalize flag of the TDT *sink* channel to 'Y' before running a measurement to acquire normalized data. Normalized Response unit can be set to VOLT (default) or GAIN. The normalize risetime can also be varied with the same limitation described above.

Differential TDR / TDT Capability

New addition to TDR driver: Differential TDR/TDT capabilities.

Two new entries have been added to the Agilent 54750 Instrument table:

Differential Mode

Set the instrument in differential mode.

Channel 1 and 2 are the TDR channels.

The differential stimulus on channel 1 and 2 can be Differential (DIFF) or Common (COMM).

Default is no differential stimulus (NONE).

Once the instrument has been calibrated in differential Response mode, the response reading can be set to Differential (DIFF) Mode or Common (COMM).

Note that this field is active only when the Normalize Flag of the response channels is set to yes.

Default is DIFF.

To make TDR differential measurements, place the Agilent 54754A plug-in in the first 2 instrument slots (channel 1 and 2).

In the IC-CAP measurement page insert 1 input of type TDR (Unit TDR1 or CH1).

Insert 1 input of Mode T (Type LIN) and set the time interval and the number of points.

Insert 2 outputs of Mode V monitoring channel 1 and 2.

In the 54750 Instrument Option Table, set the Differential Mode to DIFF or COMM.

To measure raw data simply set the Normalize flags of CH1 and CH2 to N and run the measurements.

To measure normalized data, perform the TDR normalization before running the measurements. Follow the instructions in the 54754 manual to calibrate in differential TDR mode.

Once the instrument has been successfully calibrated, set the Normalize Mode to TDR, set Differential Response Mode to DIFF or COMM. To measure the normalized response simply set the Normalize flag of channel 1 and 2 to yes.

Summary differential TDR

Differential Mode	Differential Response Mode	Response Mode	CH1	CH2
Raw DIFF/COMM	Not Relevant	Nor relevant	N	N
Norm DIFF/COMM	DIFF/COMM	TDR	Y	Y

To make TDT differential measurements place 1 Agilent 54754A plug-in in the first 2 instrument slots (channel 1 and 2) and second 54754 plug-in in the third and fourth slots. When measuring differential TDT, the driver assumes that Channel 1 and 2 supply the differential stimulus (input).

In the IC-CAP measurement setup page insert 1 input of type TDR (Unit TDR1 or CH1).

Insert 1 input of Mode T (Type LIN) and set the time interval and the number of points.

Insert 4 outputs of Mode V monitoring channel 1 to 4. In the 54750 Instrument Option Table, set the Differential Mode to DIFF or COMM.

To measure raw data simply set the Normalize Flags of CH1,CH2,CH3 and CH4 to N and run the measurements.

To measure normalized data, the user needs to perform the TDT normalization before running the measurements.

Follow the instructions in the 54754 manual on how to calibrate in differential TDT mode.

Once the instrument has been successfully calibrated, set the Normalize Mode to TDT, set Differential Response Mode to DIFF or COMM.

To measure the normalized response simply set the normalized flag of channels 3 and 4 to yes.

Summary differential TDT:

Differential Mode	Differential Response Mode	Response Mode	CH1	CH2	CH3	CH4
Raw DIFF/COMM	Not Relevant	Not relevant	N	N	N	N
Norm DIFF/COMM	DIFF/COMM	TDT	N	N	Y	Y

The following table describes the HP 54750 options and default values, where applicable.

Table 38 HP 54750 Options Table

Option	Description
Hold Time	Time, in seconds, prior to performing time-domain measurements. Default = 0

Table 38 HP 54750 Options Table (continued)

Option	Description
Averages	Number of averages per sample. Min = 1 (off), Max = 4096. Default = 16
Normalization Mode	Two modes supported for calibration and measurements: TDR or TDT. Default = TDR
Normalized Response Unit	Sets the type of unit for the acquired normalized response. Possible choices are VOLT, REF or OHM for TDR type measurements and VOLT or GAIN for TDT measurements. Default = VOLT
Normalized Response Risetime	Set the risetime for the normalized response. Minimum risetime depends on number of points. In case specified rise time is greater than the minimum allowed for that number of points, IC-CAP will set the minimum possible value. Default = 40 psec
CHn Probe Attenuation	Probe Input impedance is always 50 ohm. Specifying the attenuation of the probe permits the oscilloscope to generate data in which the probe attenuation is corrected out. For example, set it to 10 if the channel 1 probe provides a divide by 10 functionality. Values between 0.9 and 1000 are accepted. Default = 1.0
CHn Offset	DC offset value of Channel 1, in volts. This does not directly affect waveforms returned from the oscilloscope. However, an improper setting can cause the instrument to fail when measuring pulse parameters, such as RISETIME. Set this to a value close to the middle of the expected range of the output voltage waveform; this will maximize the instrument's ability to achieve high resolution without experiencing clipping. Valid range is ±250V. Default = 200.0 mV
CHn Scale	Default = 100.0 mV/div.
CHn Normalize	Normalization Flag. When set to 'Y', IC-CAP acquires the normalized response with unit as specified in The Normalized Response Unit. Default = N
TRG Probe Attenuation	Default = 1.0

Table 38 HP 54750 Options Table (continued)

Option	Description
TRG Slope	Specifies triggering on a rising (+) or falling (–) edge. Default = +
TRG Level	Voltage threshold at which triggering occurs. Range depends on attenuation. Default = 0.0 mV
TRG Slot	Choose the input trigger channel. For example, when 54754 plug-in is present on slot 1 and 2, trigger will be on slot 2. When another TDR plug-in is present on slot 3 and 4, slot 4 is another possible choice for trigger. Default = 2
TRG Mode	Used when acquiring a waveform not in TDR mode (internal trigger is used in that case). Possible choices are freerun (FREE) usually used for periodic waveform or triggered (TRIG) for transients. Default = FREE
Delay for timeout	Increase this delay when acquiring a large number of points or averages. This gives more time for the instrument to digitize the waveform and save it into memory. Default = 3
Init Command	Use to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = None

Pulse Generators

This section describes the HP 8130 and the HP 8131 pulse generators.

HP 8130 Pulse Generator

The HP 8130 is a programmable pulse generator controllable by IC-CAP. It provides excellent features for time-domain characterization using pulse stimuli. The following pulse characteristics are programmable:

- Period, Width, and Delay
- Risetime and Falltime
- Initial and Pulsed Voltage Levels

IC-CAP assigns the following name to the channel 1 output unit:

- PULSE1

The HP 8130 offers a fixed source impedance of 50 ohms. Pulse period can be varied from 3 nsec to 99.9 msec. Rise and falltimes can be varied from 670 psec to 100 µsec. The output voltage range is from −5.2 to +5.2V, but the maximum voltage swing must be less than or equal to 5.2V. A complementary output signal is available (refer to Table 39).

A Setup configured for measurements using the HP 8130, along with HP 54120 Series digitizing oscilloscopes is in the model file *54120.demo.mdl*. Additional information about this demonstration file is available in Appendix G, “54120 Demo.” These files also include examples using an HP 54120 Series oscilloscope with no pulse generator, or with a manually controlled pulse generator. The “54120 Demo” also provides hints for obtaining good alignment between measured and simulated waveforms.

The following table describes the HP 8131 options and their default values, where applicable.

Table 39 HP 8130 Options

Option	Description
Width at Top	Flag provided to aid simulator compatibility. The HP 8130 defines pulse width to include the top section of the pulse plus one-half of the rising and falling edges. SPICE defines pulse width to include the top of the pulse only. For compatibility with SPICE, set this option to Yes (the 8130 pulse will become wider). Default = No
Enable Comp Out	If Yes, complementary data can be obtained by cabling to the complementary output connector on the HP 8130. Default = No
Pulse Delay Offset	The HP 8130 has a delay between its trigger output and signal output (SPICE has nothing like this). The value is added to the TDR or PULSE sweep *Delay* value. Positive values will shift the waveform to the right; negative values will shift the waveform to the left. This option permits one to align the simulated and measured waveforms. The option may need adjustment if the period is changed. Additional hints about the use of this option are provided in Appendix G, "54120 Demo," in the section *Aligning Data.* Default = 0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

HP 8131 Pulse Generator

The HP 8131 is a programmable pulse generator controllable by IC-CAP. It provides excellent features for time-domain characterization using pulse stimuli. The following pulse characteristics are programmable:

- Period, Width, and Delay
- Initial and Pulsed Voltage Levels

IC-CAP assigns the following name to the channel 1 output unit:

PULSE1

The HP 8131 offers a fixed source impedance of 50 ohms. Pulse period can be varied from 2 nsec to 99.9 msec. Rise and fall times are fixed <200 psec; if >200 psec, IC-CAP will issue a warning *PULSE1 Rise/Fall time fixed at less than 200ps*.

The output voltage range is from −5.0 to +5.0V; the maximum voltage swing must be less than or equal to 5.0V. The offset voltage is from -4.95V to +4.95V. A complementary output signal is available (refer to Table 40).

A Setup configured for measurements using the HP 8131, along with HP 54120 Series digitizing oscilloscopes is in the model file *54120.demo.mdl*. Additional information about this demonstration file is available *Appendix G*, "54120 Demo." These files also include examples using a HP 54120 Series oscilloscope without a pulse generator, or with a manually controlled pulse generator. The "54120 Demo" also provides hints for obtaining good alignment between measured and simulated waveforms.

The following table describes the HP 8131 options and their default values, where applicable.

Table 40 Options for the HP 8131

Option	Description
Width at Top	Flag provided to aid compatibility with SPICE and other simulators. The HP 8131 defines pulse width to include the top section of the pulse plus one-half of the rising and falling edges. SPICE defines pulse width to include only the top of the pulse; as a result, SPICE pulses are wider. For SPICE compatibility, set this option to Yes. Default = No
Enable Comp Out	If Yes, complementary data can be obtained by cabling to the complementary output connector on the HP 8131. Default = No

Table 40 Options for the HP 8131 (continued)

Option	Description
Pulse Delay Offset	The HP 8131 has a delay between its trigger output and signal output (SPICE does not). The value is added to the TDR or PULSE sweep *Delay* value. Positive values will shift the waveform to the right; negative values will shift the waveform to the left. This option permits alignment of simulated and measured waveforms. The option may need adjustment if the period is changed. Additional hints about the use of this option are provided in Appendix G, "54120 Demo," in the section *Aligning Data*. Default = 0
Init Command	Command field to set the instrument to a mode not supported by the option table. This command is sent at the end of instrument initialization for each measurement. Normal C escape characters such as \n (new line) are available. Default = none

Dynamic Signal Analyzer

IC-CAP supports the HP/Agilent 35670A dynamic signal analyzer.

HP / Agilent 35670A Dynamic Signal Analyzer

The HP/Agilent 35670A portable 2- or 4-channel dynamic signal analyzer evaluates signals and devices under 102.4 kHz real-time rate at 800 lines of resolution. It provides spectrum, network, and time- and amplitude-domain measurements from virtually DC to slightly over 100 kHz.

IC-CAP assigns the following names to the units:

CHn	Channel Unit (1 and 2)
SRC	Source Unit

The following table describes the HP/Agilent 35670A options and their default values, where applicable.

Table 41 HP / Agilent 35670A Options

Option	Description
Hold Time	Time delay, in seconds, before each primary sweep begins.
Delay Time	Time delay, in seconds, before each sweep point is measured.
Averages	Defines the averaging of the instrument. Maximum is 9,999,999.
Source Mode	Source waveforms: (R) random noise, (B) burst random, (P) periodic chirp, or (S) fixed sine.
DC Offset	Specifies a DC offset for the source output.
Source Freq	Sets the frequency of the sine source.
Window Type	Type of windowing function: (H) Hanning, (U) uniform, (F) flat or (E) exponential.

Table 41 HP/Agilent 35670A Options (continued)

Option	Description
CHn Units	Vertical unit for the specified display's Y axis: (V) volts, (V2) square volts, (V/RTHZ) square root power spectral density, or (V2/HZ) power spectral density.
Init Command	Extra command to initialize the instrument to a certain mode.

2 Drivers

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This chapter describes prober and matrix driver functions, prober settings and commands, the prober driver test program, and using OMI to add drivers.

Prober Drivers

A prober driver is a set of *USERC* functions designed to control an IC wafer prober from an IC-CAP macro program. There are 3 types of probers (an initial call declares which type is in use) with these symbolic names:

- EG1034X (ElectroGlas 1034X), EG2001X (ElectroGlas 2001X)
- APM3000A (and APM6000A and APM7000A) (TSK APM models)
- SUMMIT10K (Cascade SUMMIT 10000)

These probers share the same driver functions. External user functions and internal design functions, as well as prober settings and commands, are described in this section.

Additional TIS prober drivers required the renaming of native IC-CAP prober functions from *prober_xxxx()* to *icprober_xxxx()*. This only affects systems where the *prober.c* file has been customized in the OMI environment, and will *not* affect previously-written macros. See the Readme file in *$ICCAP_ROOT/src/README* for information about these functions.

To provide easier manipulation of a raw GPIB device file, IC-CAP offers a set of low-level I/O functions named *ice_hpib_xxxx*. The declarations of these functions are found in *icedil.h*; their definitions are in *icedil.c*. Both files are provided as C source files. For more information on these I/O functions, see Appendix I, “icedil Functions” in online help. Driver functions are contained in the directory *$ICCAP_ROOT/src* in the files shown in the following table.

Table 42 Prober Driver Source Files

File Name	Description
prober.h	Prober call prototypes for *userc.c*
prober.c	Actual code for each prober function
icedil.h	Low level I/O call prototypes for *prober.c*

Table 42 Prober Driver Source Files

File Name	Description
icedil.c	Actual code for each *ice_hpib_xxxx* call
testprob.c	Small interactive program to test the driver
run_testprob	Properly sets your shared library lookup path and runs ./testprob if it exists, otherwise it runs $ICCAP_ROOT/bin/testprob. ICCAP_ROOT must be properly set in your environment for run_testprob to work.

A custom driver can be added by editing *prober.c* in *$ICCAP_ROOT/src* and generating a new shared library file, *libicuserc.<ext>* (where *ext* is a platform-specific extension) because all prober drivers are written in C and treated as library functions.

- For information on *libicuserc*, refer to "Creating a New Shared Library" on page 201.
- For details regarding adding library functions, refer to "Creating C Language Functions in IC-CAP" in the *IC-CAP User's Guide*.

Source code is provided with this open interface. Recompilation and relinking are necessary if this driver is user-modified.

External Prober User Functions

This section describes the external user functions.

Prober_debug This function takes 2 arguments and sets the internal flags. The first argument defines the debug flag; when it is 1, all debugging information is displayed in the Status window. The second argument defines the stop flag; when it is 1, the Macro execution stops when an error is detected. After *Prober_init()*, the debug flag is off (0) and the stop flag is on (1). This function does not exist in TIS. This function always returns 0. An example call is:

```
x = Prober_debug (1, 0);
```

Every function looks at this internal debug flag and prints out any GPIB commands it is going to send, or a string it just received from the prober.

Prober_init This function must be called before any other prober calls are made in a Macro program. This function takes a GPIB address of the prober, flat orientation, prober type name, and a raw GPIB interface name to which the prober is connected. The flat orientation is usually 0, 90, 180, or 270. The function returns 0 when prober initialization is successful and –1 when it fails. The following table lists the GPIB configuration recommended for HP 4062UX.

NOTE A raw GPIB interface name is different for each platform. Refer to the following table for this name. A separate GPIB interface may be necessary if the given prober does not conform to IEEE 488 standard.

Table 43 Standard HP 4062UX Configuration

Select Code	Devices
7 or 27	Instruments and Switching Matrix
25	Wafer Prober

For a Sun SPARC computer, use the following call because a National Instruments GPIB card has this name by default:

```
x = Prober_init (1, 0, “EG1034X”, “/dev/gpib0”);
```

For an HP 700 Series computer, use the following call because it involves a symbolic name rather than a GPIB interface filename:

```
x = Prober_init (1, 0, “EG1034X”, “hpib”);
```

This function also checks the prober type and sets the internal prober type flag for subsequent driver calls. It closes its private unit descriptor from any previous prober access, opens the given GPIB interface file and keeps a new entity id. It then calls an appropriate subfunction, which does the prober-dependent initialization.

Prober_reset This function takes no arguments and sets the prober to Local mode. It returns 0 when successful and 1 when it fails. This function is not available for EG1034X (for which it is a no-operation). An example call is:

```
x = Prober_reset ();
```

This function clears the interface file and sends a selected device clear command to the prober.

Prober_status This function takes no arguments and returns 3 Real values in 1 array. The first element of the array indicates whether the prober is Remote (1) or Local (0). The second element indicates whether the edge contact is detected (1) or not (0). The last element indicates whether the Cassette is empty (1) or not (0). An example call is:

```
status = Prober_status ();
if (status[0] == 1) then ...
```

This function sends a query command to the prober and receives information about Remote/Local state as well as the edge sensor output. The Cassette Empty error is detected in the function *Phome* and referred by this function, which keeps these states and returns them back in an array of Real values.

Pdown This function takes no arguments and lowers the chuck of the wafer prober. It returns 0 when successful and –1 when it fails. An example call is:

```
x = Pdown ();
```

Phome This function takes no arguments and performs several tasks depending on the prober type. It returns 0 when successful and –1 when it fails. When it detects a Cassette Empty error, it returns 1. An example call is:

```
x = Phome ();
```

This function calls a subfunction based on the prober type. A subfunction actually does the prober-dependent operation appropriate for Phome.

NOTE

Set the SUMMIT 10000 prober to *Remote* manually after this function to move the chuck to its Load position and turn the mode to *Manual* for wafer alignment.

Pimove Like *Pmove*, this function takes 2 arguments and moves the chuck relative to the current position. It returns 0 when successful and –1 when it fails. An example call is:

```
x = Pimove (1, 0);
```

Pink This function takes 1 argument and triggers the specified inker. It returns 0 when successful or –1 when it fails. EG1034X and SUMMIT10K probers do not support an inker, so this function is a no-operation for them. An example call is:

```
x = Pink (1);
```

Pmove This function takes 2 arguments and moves the chuck to the specified absolute coordinates established by *Pscale* and *Porig*. The first argument specifies the new X position and the second specifies the new Y position. It returns 0 when successful and –1 when it fails. An example call is:

```
x = Pmove (2, 4);
```

This function calculates how many machine units the chuck must move relative to the current position, and sends an appropriate GPIB command to move the chuck. It also updates its internal variables to keep track of the position.

Porig This function takes 2 numbers and defines these numbers as X and Y coordinates of the current chuck position. This function must be called before any Pmove or Pimove functions. It always returns 0. An example call is:

```
x = Porig (0, 0);
```

This function stores the given numbers in its private variables.

Ppos This function takes no arguments and returns 2 Real values in an array, indicating the current die X and Y position being probed. The first element of the array is the X coordinate and the second is the Y coordinate. An example call is:

```
position = Ppos ();
print “X = “; position[0], “Y = “; position[1];
```

This function copies its private variables (which indicate the current position) and returns them.

Pscale This function takes the die X and Y dimensions in micrometers. These numbers are later used in *Pmove*, *Porig*, and *Pimove* functions. It always returns 0. An example call is:

```
x = Pscale (5000, 5000);
```

This function stores the given numbers in its private variables.

Pup This function takes no arguments and raises the chuck of the wafer prober so that probe pins come in contact with the wafer. It returns 0 when successful and –1 when it fails. An example call is:

```
x = Pup ();
```

Internal Prober Functions

Several internal functions support the user functions to customize the prober driver. For each algorithm, refer to the *prober.c* source file.

prober_get_err This function takes 1 argument and calls a subfunction depending on the prober type. Each subfunction reads any error status from the prober. If it encounters an unknown error, it prints out the given number with an error message to the Status window. It always returns 0. An example call is:

```
ret = prober_get_err(n);
```

prober_get_srq This function takes no arguments and returns 0 (no SRQ) or 1 (SRQ) depending on the SRQ line of the device file. An example call is:

```
ret = prober_get_srq();
```

prober_message This function takes 1 argument, a pointer to a string, and prints an error message to the Status window such as <*name*>*: unknown prober type,* where <*name*> is replaced with the given string. An example call is:

```
ret = prober_message("Prober_reset");
```

prober_precheck This function takes no arguments and checks prober state such as Remote/Local and SRQ. It returns 0 when successful and –1 when it fails. An example call is:

```
ret = prober_precheck();
```

prober_response This function takes 1 argument that is either a pointer to a character array or null. It calls a subfunction depending on the prober type and each subfunction reads any status information from the prober. Internal flags are set according to the status and any errors are reported. It returns 0 if there is no error. If a non-null pointer is given, a received string from the prober is returned using this pointer. An example call is:

```
char buffer[PSIZE];
ret = prober_response(buffer);
```

prober_spoll This function takes no arguments and performs serial polls in a prober-dependent way that may be different from the standard IEEE 488 implementation. It returns a status byte from the prober. An example call is:

```
ret = prober_spoll();
```

prober_wait_srq This function takes 1 argument that is a timeout value in seconds, and waits for SRQ to be asserted. It returns 0 when SRQ is detected and –1 when a timeout or error occurs. An example call is:

```
ret = prober_wait_srq(60.0);   /* 60 sec */
```

Prober Settings and Commands

This section describes the correct IC-CAP wafer prober settings and their associated GPIB commands.

EG1034X

This simple manual prober uses 2 settings. (Note that IC-CAP uses SRQ whereas HP 4062UX does not.)

- GPIB Address: Any
- SRQ Switch: Enabled

The following table lists the EG1034X GPIB commands. (Note that IC-CAP uses the MM command to move the chuck; HP 4062UX uses the MO commands for the EG1034X.)

Table 44 EG1034X GPIB Commands

Item	Command	Reply	Item	Command	Reply
Move Chuck	MM	MC	Chuck Home	HO	MC
Chuck Up	ZU	MC	Chuck Status	?S	SZ...
Chuck Down	ZD	MC			

EG2001X

This driver is tested with a prober software version called *AC*. The parameters listed in the following table must be set to control this prober. Note that the I/O PROTOCOL is different from the one for HP 4062UX. The Die Size is optional, but is included because IC-CAP does not set the size for manual operations.

Table 45 EG2001X Settings

Parameter	Value	Parameter	Value
METRIC/ENGLISH	METRIC	AUTO LOAD	ENB if available
DIE X and Y SIZE	Any	AUTO ALIGN	ENB if available
AUTO PROBER PAT.	EXTERNAL	AUTO PROFILE	ENB if available
AUTO DIAMETER	ENB	MF/MC on X-Y	ENB
Z-TRAVELING MODE	EDGE-SEN	MF/MC on Z	DIS
I/O PROTOCOL	ENHANCED	MF/MC on OPT.	ENB
I/O PORT	GPIB-SP	MF/MC on others	DIS
GPIB ADDRESS	Any		
SRQ SWITCH	ENB		

The following table lists the EG2001X GPIB commands. Note that *Chuck Home* uses both UL and LO commands (HP 4062UX uses LO).

Table 46 EG2001X GPIB Commands

Item	Command	Reply	Item	Command	Reply
Move Chuck	MM	MC or MF	Auto Profile	PZ	MC or MF
Chuck Up	ZU		Auto Align	AA	MC or MF
Chuck Down	ZD		Trigger Inker	IK	MC or MF
Chuck Home	UL/LO	MC or MF	Chuck Status	?S	SZ...

APM3000A, APM6000A, APM7000A

This prober uses the following settings:

- GPIB Address: Any
- Mode Switches: 3-4 OFF, 3-5 ON, 23-4 ON

The following table lists the commands.

Table 47 APM3000A, APM6000A, and APM7000ACommands

Item	Command	Reply	Item	Command	Reply
Move Chuck	A	65	CPU Halt	T	
Chuck Up	Z	67 or 73	Trigger Inker	M	69
Chuck Down	D	68	Chuck Home	L	70 or 76

SUMMIT10K

This driver waits for an SRQ for an operation completed. With Summit Software version 2.10, the F10 key enables *Remote* mode. This prober uses the following settings.

- COMMUNICATION PROTOCOL: GPIB
- COMMAND SET: native
- DISP REMOTE CMDS: off
- BUS ADDRESS: any
- TIMEOUT: 30.0
- CONTROL MODE: remote

SUSS PA 150, PA 200

The SUSS ProberBench Interface developed by Karl Suss for IC-CAP is provided as a convenience, but is not supported by Agilent Technologies. The prober driver supports all functions described in "External Prober User Functions" on page 155 and "Internal Prober Functions" on page 159 except *prober_spoll*(), *prober_get_srq*(), and *prober_wait_srq*(). In addition to these IC-CAP functions, you can use the complete ProberBench command set (150 functions) to enhance operation. For information on these functions, refer to the ProberBench User Manual. For information on writing macros to control the prober, refer to "Writing a Macro" on page 185.

The SUSS PA 150 and PA 200 Semiautomatic Probers utilize a Microsoft Windows-based user interface running on an IBM-compatible PC. The IC-CAP environment communicates with the prober via a macro over the IEEE 488 bus.

The required PC IEEE488 control hardware is: IOtech Personal488/AT.

The PC configuration must use the following values for the settings shown; all other settings use default values:

Interface Type:	GP488B
Name:	IEEE
IEEE Bus Address:	22
System Controller:	Off
Time-out (ms):	3000
Interface Bus Address:	02E1
DMA Channel:	None
Interrupt:	None

Prober Driver Test Program

This section describes the prober test program *testprob,* which is provided with C source code. This program runs independently from IC-CAP and interactively calls driver functions to test an Agilent-supplied or a custom driver.

The file for this program is located in *$ICCAP_ROOT/src* and is called *testprob.c.* It includes the test program main. The Makefile offers an option to build this test program. This program is linked with *prober.o, iceswn.o, icedil.o,* a GPIB library to exercise both prober and switching matrix drivers. If *testprob* has been rebuilt with a custom driver, use an absolute path to specify the new *testprob* because *$ICCAP_ROOT/bin* has another, original *testprob* executable.

The *testprob* executable is an interactive program that gets user input from its *stdin* and calls an appropriate driver function, then prints out the return value(s) of the driver function to the Status window.

The *run_testprob* script properly sets your shared library lookup path and runs *./testprob* if it exists, otherwise it runs *$ICCAP_ROOT/bin/testprob*. Therefore, you should use the *run_testprob* script to run *testprob*. Make sure $ICCAP_ROOT is properly set in your environment, then type `run_testprob`.

An actual prober (matrix) must be connected to a raw GPIB device file in order to perform driver (matrix) tests. Off-line testing is not available with this program.

This program expects to see a function name and its arguments as if they appeared in an IC-CAP Macro program. However an argument list cannot include another function, that is, nesting is not allowed.

A command example is:

```
Prober_init(1, 0, “EG1034X”, “hpib”)
```

The currently supported functions are shown next.

Connect	Prober_debug
FNPort	Prober_init
Pdown	Prober_reset
Phome	Prober_status
Pimove	Pscale
Pink	Pup
Pmove	SWM_debug
Porig	SWM_init
Ppos	Wait

NOTE Any line starting with # is treated as a comment and is ignored. A blank line is skipped (this is helpful when a file is used to supply input to this program).

Because this test program is not a real Macro interpreter, it has the following restrictions:

- No control constructs
- No variables
- No nesting of functions
- No function library other than the prober and matrix driver
- No capability to execute IC-CAP Macro programs.

Because nesting is not supported, the *Connect* function needs a port address such as 32701 instead of *FNPort(1)*. Refer to the *HP 4062UX Programming Reference* for more information about port addresses.

Matrix Drivers

A matrix driver is a set of *USERC* functions designed to control the switching matrices through an HP 4084 controller from an IC-CAP Macro program. The matrix driver supports the matrices listed in Table 48.

External user functions and internal design functions are described in this section. They are designed to be compatible with HP 4062UX TIS where possible.

Source files for this matrix driver are *iceswm.h* and *iceswm.c*. The header file *iceswm.h* is included in *userc.c* so that the function names can appear in the Function List of IC-CAP.

Source code is provided with this open interface.

Table 48 Types of Matrix Drivers

Matrix	Controller	Pins	Device
HP 4085A	HP 4084A	48	HP 4062A and HP 4062B
HP 4085B	HP 4084B	48	HP 4062C and HP 4062UX
HP 4089A	HP 4084B	96	same as above, with 2 controllers

External Matrix Driver User Functions

This section describes the matrix driver external user functions.

SWM_debug This function takes 1 argument and sets the internal debug flag. When the argument is 1, debugging information is printed out to the Status window; when the argument is 0, printing is turned off. It always returns 0. This function does not exist in TIS. An example call is:

```
x = SWM_debug(1)
```

Every function looks at this flag and prints out any GPIB commands it is going to send, or a string it just received from a matrix controller.

SWM_init This function takes 2 GPIB addresses, a matrix name, and a raw GPIB interface name to which the matrix is connected. The first GPIB address is for the block 1 (usually 19) and the second is for the block 2 (22). However, a different address can be assigned for each matrix controller. For the HP 4085A and HP 4085B (both 48-pin systems), the second address is used as the controller address, and the first address is ignored. It returns 0 when successful and –1 when it fails. This function does not exist in TIS. An example call is:

```
x = SWM_init (19, 22, “HP4089A”, “hpib”); ! for 96-pin
```

or

```
x = SWM_init (0, 22, “HP4085B”, “hpib”);  ! for 48-pin
```

This function checks the matrix type and sets the internal type flag for subsequent matrix calls. It closes its private entity id from a previous matrix access (when it exists), and opens the given raw GPIB device file. Then it calls an internal function *swm_init_unit* to reset a controller. This clears all pins and ports.

Connect This function takes a port address and a pin number and connects the given port to the pin. The port address is either 0 or from 32701 to 32711, inclusive. The pin number is 0 or from 1 to 48/96 inclusive. When a pin card does not exist for the given pin number, it gives an error message and aborts the Macro execution.

An example call is:

```
x = Connect(32701, 25);
```

This function sends GPIB commands to the matrix controller and either connects or disconnects the specified port and pin. The following table lists argument combinations.

Table 49 Argument Combinations

Port Address	Pin Number	Description
0	0	Disconnect all pins from all ports.
0	X	Disconnect pin X from its connected port.
X	0	Disconnect all pins connected to port X.

Table 49 Argument Combinations

Port Address	Pin Number	Description
X	Y	Connect port X to pin Y.

As in TIS, multiple pins can be connected to 1 port by calling this function several times. Pin numbers 1 through 48 belong to block 1; pin numbers 49 through 96 belong to block 2. When a 96-pin matrix is used, do not connect block 1 and block 2 pins to 1 single port. Because this function does not include switching delay, allow enough wait time before and after measurement to prevent relay damage. Virtual Front Panel (VFP) is not supported.

FNPort This function takes a port number and returns a port address for Connect. This allows compatibility with the HP 4062UX. An example call is:

```
port = FNPort(1);
```

Wait This function takes a wait time, in seconds, to give a necessary delay to wait until SMU outputs become zero for dry switching. This function does not exist in TIS. It returns 0 when successful or –1 when it fails. An example call is:

```
x = Wait (0.1) ! 100ms delay;
```

Internal Matrix Driver Functions

The internal functions described next support the user functions. Refer to the source file for each algorithm.

swm_connect_pin This function takes a GPIB address of a controller, a port number, and a pin number. It sends a *Pin Connect* command to the controller, and is called from *swm_connect* (Connect) to actually perform the pin connection and disconnection.

swm_connect_port This function takes a GPIB address and a port number to send a *Port Connect* command to the controller, which manages input relays of an HP 4089A matrix.

swm_cut_port_pin This function takes a GPIB address and a pin number to cut the pin connection when a 96-pin matrix is used. It also checks if the port to which the pin was connected can be turned off; if it can (both Force and Guard are off), it turns off this port.

NOTE

When a switching matrix controller shares a single GPIB with other instruments, set the system variable *INST_START_ADDR* to a value greater than the matrix controller's GPIB address. This prevents IC-CAP from accessing the controller while performing *Rebuild* (instrument list).

swm_init_unit This function takes a file designator (or *eid*, a small integer usually obtained by calling the *open* system function) and a GPIB address of a matrix controller. It is called from *swm_init* to initialize a controller and clear all pins and ports for which the controller is responsible.

swm_parse_err This function takes a status byte sent from a matrix controller and determines the cause of an SRQ. If there is no error, it returns 0 to allow the caller to keep running. If there is an error, it returns –1 to abort the execution of the caller.

swm_release_port This function takes a GPIB address and a port number to send a *Port Disconnect* command to the controller only when a 96-pin matrix is used. Because block 1 and block 2 pins should not be connected to a single port, a disconnect request such as *Connect(32701, 0)* not only cuts the connection between a port and a pin, but also disconnects the input relays of the port.

Using IC-CAP with B2200A / B2201 Low-Leakage Mainframe Driver

This section describes the transforms implemented for the B2200A/B2201 Low-Leakage Mainframe Driver.

List of the transforms:

- B2200_bias_card_enable
- B2200_bias_ch_enable
- B2200_bias_enable
- B2200_bias_init
- B2200_close_interface
- B2200_connect
- B2200_couple_enable
- B2200_couple_setup
- B2200_debug
- B2200_disconnect_card
- B2200_GPIB_handler
- B2200_ground_card_enable
- B2200_ground_enable
- B2200_ground_init
- B2200_ground _outch_enable
- B2200_ground _unused_inputs
- B2200_init
- B2200_open_interface

The following sections describe these transforms. For more details about the Agilent B2200A/B2201A, see its *User Guide*.

Utility Functions

B2200_debug When set to 1, prints out all command strings sent to the instrument. This flag is common to all B2200A's on the bus, regardless of their GPIB address.

```
B2200_debug(<flag>)
```

where:

<flag> is "1", "0", "Yes", or "No".

B2200_close_interface Closes the current interface, which was opened by calling B2200_open_interface().

B2200_GPIB_handler Returns -1 if the interface has not been initialized (invalid handler). Returns a positive integer (handler) if the interface has been opened.

Returns the current interface handler. The function is provided as a utility function, which enables you to write advanced PEL code to write and read data to the B2200A using the HPIB_write and HPIB_read functions. Initializing the handler using B2200_open_interface enables you to use B2200A's built-in driver functions as well as writing PEL code to support other features that are not currently supported by the built-in functions, all in the same PEL code.

Initialization and General Configuration

B2200_open_interface Opens and initializes the GPIB interface and must be run first in the PEL program. The interface handler is saved in a static variable so that the interface will be shared by all the other B2200's function calls. You can drive multiple B2200 instruments as long as they are on the same interface bus (obviously, they must have different addresses).

```
B2200_open_interface(<Interface Name>)
```

where:

<Interface Name> is the name of the GPIB interface.

B2200_init Must be run first in the PEL program to initialize the instrument and set the configuration mode. When the instrument is in AUTO configuration mode and multiple plug-in cards are installed in the B2200 slots from

slot 1 continuously, the installed cards are then treated as one card (numbered 0). This function resets all the settings to factory default before setting the configuration mode.

This function also sets the default connection rule for the specified card. When the connection rule is FREE (default mode), each input port can be connected to multiple output ports and each output port can be connected to multiple input ports. When the connection is SINGLE, each input port can be connected to only one output. Connection sequence specifies the open/close sequence of the relays when changing from an existing connection to a new connection.

```
B2200_init(<addr>,<cardNumber>,<config>,<connectionRule>,
<connectionSequence>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<cardNumber> is 0(auto), 1, 2, 3, or 4.

<config> is "AUTO" or "NORMAL" (string input).

<connectionRule> is "FREE" or "SINGLE".

<connectionSequence> is "NSEQ", "BBM", or "MBBR".

- NSEQ (No SEQuence): Disconnect old route, connect new route.
- BBM (Break Before Make): Disconnect old route, wait, connect new route.
- MBBR (Make Before BReak): Connect new route, wait, disconnect old route.

Transforms Governing the Bias Mode

B2200_bias_init Selects the Input Bias Port for the specified card. The Input Bias Port is the dedicated bias port.

```
B2200_bias_init(<addr>, <CardNumber>, <InputBiasPort>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<InputBiasPort> is 1 to 14 (numeric input) or –1 to disable bias port.

B2200_bias_ch_enable This function bias-enables specific output ports in the channel list for the specified card. The input ports specified in the channel list are ignored since the input port is always the Bias Input Port. By default, all the outputs are bias-enabled after a reset.

```
B2200_bias_ch_enable(<addr>,<CardNumber>,<State>,<Channel list>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<State> is the output port's state (allowed values are "ENABLE", "DISABLE", "E", or "D")

<Channel list> is the list of channels, known as connection routes. Example channel list: (@10102, 10203, 10305:10307)

B2200_bias_card_enable This function bias-enables all the output ports of the specified card. By default, all ports are bias-enabled after a reset.

```
B2200_bias_card_enable(<addr>, <CardNumber>, <CardState>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<CardState> is the card output port's state (allowed values are "ENABLE", "DISABLE", "E", or "D").

B2200_bias_enable Enables the bias mode for the specified card once Input Bias Port and Enabled Output ports are specified. When Bias Mode is ON, the Input Bias Port is connected to all Bias Enabled output ports that are not

connected to any other input ports. Bias Disabled output ports are never connected to an Input Bias Port when Bias Mode is ON.

If another input port is disconnected from a bias enabled output port, this port is automatically connected to the Input Bias Port.

If another input port is connected to a Bias Enabled output port, the output port is automatically disconnected from the Bias Input Port. When Bias Mode is OFF, the Input Bias Port is the same as the other ports.

```
B2200_bias_enable(<addr>, <CardNumber>, <mode>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<mode> is "On", "Off", "1", or "0".

Transforms Governing the Ground Mode

B2200_ground_init Selects the input Ground Port for the specified card. For each card, you can specify the same or a different Ground Port. By default, the input Ground Port is port 12. The ground port should be connected to 0 V output voltage. See the Agilent B2200 *User's Guide* for details.

```
B2200_ground_init(<addr>,<CardNumber>,<InputGroundPort>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<InputGroundPort> is 1 to 14 (numeric input) or –1 to disable ground port.

B2200_ground _outch_enable Ground-enables or ground-disables output ports. When Ground Mode is turned ON, the ground-enabled output ports that have not been

connected to any other input port are connected to the input ground port. The input ports specified in channel lists are ignored since the input port is always the Input Ground Port. By default, all the outputs are ground-disabled after a reset.

```
B2200_ground _outch_enable(<addr>,<CardNumber>,<State>,
<Channel list>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<State> is the port's state (allowed values are "ENABLE", "DISABLE", "E", or "D").

<Channel list> is the list of channels, known as connection routes. Example channel list: (@10102, 10203, 10305:10307)

B2200_ground _unused_inputs Specifies the ground-enabled (or unused) input ports for the specified card. When Ground Mode is turned ON, the ground-enabled input ports that have not been connected to any other port are connected to the input Ground Port. By default, all the inputs are ground-disabled after a reset.

```
B2200_ground _unused_inputs(<addr>,<CardNumber>,<Input Channels>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, 4.

<Input Channels> is the list of input channels (e.g., "1, 2, 5"). Only input ports 1 to 8 can be defined as unused (these are the input Kelvin Ports).

B2200_ground_card_enable Enables ground-enabling for all the output ports of the specified card. By default, all ports are ground-disabled.

```
B2200_ground_card_enable(<addr>,<CardNumber>,<CardState>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<CardState> is the card output port's state (allowed values are "ENABLE", "DISABLE", "E", or "D").

B2200_ground_enable Enables the bias mode for the specified card. When Ground Mode is turned ON, the Input Ground Port (default is 12) is connected to all the Ground Enabled input/output ports that have not been connected to any other port. At Reset, Ground Mode is OFF. Ground Mode cannot be turned ON when Bias Mode is ON.

See the Agilent B2200 *User's Guide* for additional comments and restrictions.

```
B2200_ground_enable(<addr>, <CardNumber>, <mode>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, 4.

<mode> is "On", "Off", "1", or "0".

Transforms Governing the Couple Mode

B2200_couple_enable Use this function to enable or disable Couple Port mode. Couple Port mode allows synchronized connection of two adjacent input ports to two adjacent output ports.

```
B2200_couple_enable(<addr>, <CardNumber>, <Mode>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<mode> is "On", "Off", "1", or "0".

B2200_couple_setup Selects the couple ports for Kelvin connections. At Reset, no input ports are coupled.

```
B2200_couple_setup(<addr>,<CardNumber>,<ListOfCoupledPorts>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<ListOfCoupledPorts> is the list of odd number input channels (e.g., "1, 3, 5" means coupled ports are 1-2, 3-4, 5-6).

Transforms Governing the Switching

B2200_connect Connects or disconnects specified channels. Bias Mode and coupling Mode are also taken into account when a channel is closed or opened.

For example, in the list (@10102, 10203:10205), the following channels are connected or disconnected on card 1. Input port 1 to output port 2. Input port 2 to output port 3 and 5.

```
B2200_connect(<addr>,<Connect/Disconnect>,<ChannelList>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<Connect/Disconnect> is C or D.

<ChannelList> is the list of connections to close.

B2200_disconnect_card Opens all relays or channels in the specified cards.

```
B2200_disconnect_card(<addr>, <CardNumber>)
```

where:

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

Using IC-CAP with the HP 5250A Matrix Driver

This section describes the transforms implemented for the HP 5250A Switching Matrix.

NOTE The old switching box transforms that were implemented for the HP 40XX series are *not* compatible with the new ones. The instruments have different commands for switching and the 5250A has new features such as BIAS and COUPLE modes, which were not available for the old 40XX series.

List of the transforms:

- HP5250_debug
- HP5250_init
- HP5250_card_config
- HP5250_bias_init
- HP5250_bias_card
- HP5250_bias_channel
- HP5250_bias_setmode
- HP5250_couple_setup
- HP5250_couple_enable
- HP5250_connect
- HP5250_disconnect_card
- HP5250_compensate_cap
- HP5250_show()

The following sections describe these transforms. For more details about the HP 5250A, see its *User Guide*.

Utility Functions

HP5250_debug This transform is only for debugging. When the debug flag is set to 1, all the functions print out all the command strings that are sent to the instruments. Set *flag* using the values 1 or 0, or use YES or NO.

```
HP5250_debug(<flag>)
```

HP5250_compensate_cap This transform is the equivalent IC-CAP C routine for the HP BASIC capacitance compensation routine called Ccompen_5250 supplied with the HP 5250A. It returns a 2 by 1 matrix (2 rows, 1 column) defined as follows:

- output.11 represents compensated capacitance data [F].
- output.21 represents compensated conductance data [S].

```
HP5250_compensate_cap (RawCap, RawCond, Freq, HPTriaxLenght,
UserTriaxLenghtHigh, UserTriaxLenghtLow, UserCoaxLenghtHigh,
UserCoaxLenghtLow)
```

where:

RawCap is Input Dataset containing raw capacitance data [F]

RawCond is the Input Dataset containing raw conductance data [S]

Freq is the measured frequency [Hz]

HPTriaxLenght is the HP Triax Cable Length [m]

*UserTriaxLenghtHigh*is the user Triax Cable Length (High) [m]

UserTriaxLenghtLow is the user Triax Cable Length (Low) [m]

UserCoaxLenghtHigh is the user Coax Cable Length (High) [m]

UserCoaxLenghtLow is the user Coax Cable Length (Low) [m]

HP5250_show() This transform has no inputs. It returns to the standard output (screen or file) the following data about the instrument status:

- Instrument Name
- Instrument Configuration (AUTO/NORMAL).

The following information is output for each card installed in the instrument (card 0 if the instrument is in auto configuration mode):

- Connection mode
- Connection sequence
- Input Bias Port
- Enabled Output Bias Ports
- Bias Sate (ON/OFF)
- Coupled Input Ports (only lower number is listed, e.g., “3,5” means ports 3 and 4 are coupled
- Couple Port Mode (ON/OFF)
- Connection Matrix Inputs(10)xOutputs(12,24,36, or48). The following table shows an output example of the Channel Matrix State where Card 1 is a 10x12 matrix switch. A “1” in a matrix cell means the connection is closed.

		Output Ports											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	1	0	0	0	1	0	0	0	0	0	0	0	0
	2	1	1	1	1	1	0	0	0	0	0	0	0
	3	0	1	0	0	0	0	0	0	0	0	0	0
Input	**4**	0	0	0	0	0	0	0	0	0	0	0	0
Ports	**5**	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0

Initialization and General Configuration

HP5250_init This transform must be run first to initialize the instrument with the address and interface. Using this transform the configuration mode can be set to AUTO. When the instrument is in AUTO configuration mode the same type of card must be installed in the HP 5250 slots from slot 1 continuously. The installed cards are then treated as 1 card (numbered 0).

```
HP5250_init (BusAddress, "Interface", "Configuration")
```

where

BusAddress is interface bus address (default is *22*)

"Interface" is interface name (default is *hpib*)

"Configuration" is AUTO/NORMAL A/N (default is *NORMAL*)

HP5250_card_config This transform is used to change the default configuration for the specified card. When the connection rule is FREE (default mode), each input port can be connected to multiple output ports and each output port can be connected to multiple input ports. When the connection is SINGLE, each input port can be connected to only 1 output. Connection sequence specifies the open/close sequence of the relays when changing from an existing connection to a new connection.

```
HP5250_card_config (CardNumber, "ConnRule", "ConnSequence")
```

where

CardNumber specifies the card (0 for AUTO configuration mode)

"*ConnRule*" is FREE/SINGLE (default is *FREE*)

"*ConnSequence*" is NSEQ/BBM/MBBR (default is *BBM*)

- NSEQ (No SEQuence): Disconnect old route, connect new route.
- BBM (Break Before Make): Disconnect old route, wait, connect new route.

- MBBR (Make Before BReak): Connect new route, wait, disconnect old route.

Transforms Governing the Bias Mode

HP5250_bias_init This transform selects the bias port. When using the HP/Agilent E5255A card, the Input Bias Port is the dedicated bias port; however, for the HP/Agilent E5252A the Input Bias Port must be selected using this function.

```
HP5250_bias_init(CardNumber, InputBiasPort)
```

where

Card Number specifies the card (allowed values 0-4, 0 = auto configuration mode)

InputBiasPort specifies the input bias port number (allowed values are 1-10)

HP5250_bias_card This transform bias-enables all the output ports for the specified card.

```
HP5250_bias_card(CardNumber, "CardState")
```

where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

"*CardState*" is the card's state (allowed values are ENABLE/DISABLE or E/D)

HP5250_bias_channel This transform bias-enables the specified output ports in the channel list. Note that the input ports are ignored since the input port is always the Bias Input Port.

```
HP5250_bias_channel ("State", "Channel list")
```

where

"*State*" is the output port's state (allowed values are ENABLE/DISABLE or E/D)

"*Channel list*" is the list of channels, known as connection routes

Example channel list: (@10102, 10203, 10305:10307)

HP5250_bias_setmode This transform enables the bias mode for the specified card once Input Bias Port and Enabled Output ports have been specified.

```
HP5250_bias_setmode (CardNumber, "BiasMode")
```

where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

"*BiasMode*" sets the bias mode on or off (allowed values are ON/OFF or 1/0)

When Bias Mode is ON, the Input Bias Port is connected to all the Bias Enabled output ports that are not connected to any other input ports. Bias Disabled output ports are never connected to an Input Bias Port when Bias Mode is ON.

- If another input port is disconnected from a bias enabled output port, this port is automatically connected to the Input Bias Port.
- If another input port is connected to a Bias Enabled output port, the output port is automatically disconnected from the Bias Input port.

When Bias Mode is OFF, the Input Bias Port is the same as the other ports.

Transforms Governing the Couple Mode

HP5250_couple_setup This transform sets up couple ports for making kelvin connections.

```
HP5250_couple_setup (CardNumber, "InputPorts")
```

where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

"*InputPorts*" is the list of coupled ports

Example: In the list "1,3,5,7,9" the coupled ports are 1-2, 3-4, 5-6, 7-8, 9-10

HP5250_couple_enable This transform enables couple port mode. Couple port allows synchronized connection of 2 adjacent input ports to 2 adjacent output ports.

```
HP5250_couple_enable (CardNumber, "CoupleState")
```

where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

"*CoupleState*" is the coupled state (allowed values are ON/OFF or 1/0)

Transforms Governing the Switching

HP5250_connect This transform connects or disconnects specified channels. Note that Bias Mode and/or coupling Mode are also taken into account when a channel is closed or opened.

```
HP5250_connect ("Action", "Channel list")
```

where

"*Action*" connects or disconnects channels (allowed values are C and D)

"*Channel list*" is the list of connection routes to be switched

Example: In the list (@10102, 10203:10205), the following channels are connected or disconnected on card 1:

Input port 1 to output port 2.

Input port 2 to output port 3, 4, and 5.

HP5250_disconnect_card This transform simply opens all relays or channels in the specified cards.

```
HP5250_disconnect_card (CardNumber)
```

where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

Using IC-CAP with HP 4062UX and Prober / Matrix Drivers

This section describes how to use HP 4062UX instruments and the prober/matrix from IC-CAP for wafer device characterization. Also included in this section is information about writing a macro, controlling the prober, and conditions of which to be aware.

While the HP 4062UX is an ideal instrument for performing device characterization with IC-CAP, it is necessary to understand IC-CAP, probers, matrices, and the instruments under control. IC-CAP is an independent program from HP 4062UX TIS or VFP. It is not necessary, and can be damaging, to run the *START* program before running IC-CAP. To run IC-CAP after running the *START* program, the HP/Agilent 4142B must first be reset manually.

After running the HP 4062UX *START* program, the HP/Agilent 4142B is put into its binary mode. Because IC-CAP assumes that all the instruments to which IC-CAP is connected accept ASCII commands, IC-CAP cannot recognize the 4142B. Reset the 4142B by sending a Device Clear or by turning the instrument off and on again. To send a Device Clear to the 4142B, use the IC-CAP GPIB analyzer (Tools menu):

1 In the Instrument Setup Window, choose **Tools > Send Byte**.

2 Enter the default value `20` and choose **OK**.

NOTE Execute the *START* program to run TIS applications on the HP 4062UX, similar to a normal power-up.

Writing a Macro

While instruments like the HP/Agilent 4142B and the HP 4280A are controlled by IC-CAP with Setup tables, both the wafer prober and the switching matrix must be controlled through macro programs using the *Pxxxxx()* and

Connect() functions. The Setup table defines which measurement unit is going to force certain output. Users must perform the following actions:

1. Determine which matrix port needs to be connected to which matrix pin.
2. Write several *Connect()* functions in a macro program that invokes this Setup measurement with a *iccap_func()* statement.

The example shown in the following figure involves 4 SMUs of an HP/Agilent 4142B and measures Id_vs_Vg characteristics of an NMOS device on a wafer.

```
! Prober and Matrix Test Program
x = swm_init(19, 22, "HP4085B", "/dev/ice_raw_hpib")
x = connect(fnport(1), 15) ! SMU1 - Drain
x = connect(fnport(2),  7) ! SMU2 - Gate
x = connect(fnport(3),  8) ! SMU3 - Source
x = connect(fnport(4),  6) ! SMU4 - Bulk
x = prober_init(2, 0, "EG2001X", "/dev/ice_raw_hpib")
!
linput "Load Cassette and Press OK", msg
status = prober_status()  ! wait until Remote
while (not status[0])
   status = prober_status()
endwhile
iccap_func("/nmos2/large/idvg", "Display Plots")
!
x = pscale(8200, 8200)    ! test chip die size
x = phome()               ! goes to the first die
while (x == 0)
   x = porig(0, 0)        ! first die coordinates
   i = 0
   while (i < 5)          ! test diagonal 5 dies
      x = pdown()
      x = pmove(i, i)
      x = pup()
      print
      print "Die Position X=";i;" Y=";i;
      iccap_func("/nmos2/large/idvg", "Measure")
      iccap_func("/nmos2/large/idvg", "Extract")
      i = i + 1
   endwhile
   x = phome()            ! load next wafer
endwhile
if (x == 1) then linput "Cassette Empty. Test End.", msg
x = connect(0, 0)         ! disconnect matrix pins
```

Figure 4 Sample Wafer Test Program

Prober Control

Prober control is determined by the number of test modules, which is either single or multiple per die.

With the *Pxxxx* functions, it is assumed that there is a single test module on each die and every test module exists in the same place relative to its die origin. In this case, it is easy to control the wafer prober.

The example in Figure 4 shows the size of each die to be 8200 µm × 8200 µm. The operator first indicates to the prober where the test module is on the first die. Once the prober is set to find this test module, *Pmove()* or *Pimove()* can step to any die and probe the same test module.

When there are multiple modules per die, every module position must be calculated in microns and *Pscale(1,1)* must be called. You must know each module position relative to its die origin, and each die position relative to its wafer origin. You must calculate these numbers to move the wafer chuck to its correct probing position.

Special Conditions

When using probers and matrices, be aware of the following conditions:

Interface File A dedicated GPIB interface for a prober is recommended to avoid unknown effects on other instruments. However, if the given prober conforms to the IEEE 488 standard, it is possible to put the prober on the same GPIB with other instruments. Set the *INST_START_ADDR* system variable high enough to protect the prober from being accessed by the *Rebuild* (instrument list) operation.

Interrupt Both prober and matrix functions are simple C functions called from the Macro interpreter of IC-CAP. It is possible to interrupt any one of these functions during its GPIB communication. Therefore, whenever you interrupt the execution of a Macro program that involves prober or matrix control, it might be necessary to reset the bus. *Prober_init()*

resets its interface bus to clear any pending GPIB communications with the prober. However, *SWM_init()* only sends a Selected Device Clear to the matrix controller. If necessary, you can reset the measurement bus by choosing *Tools* > *Interface* > *Reset*.

Bus Lock The HP 4062UX can lock the measurement bus even when a TIS program is not running. Be sure that the GPIB for measurement instruments is unlocked when IC-CAP starts up. The easiest way to ensure this unlocked condition is to exit the HP BASIC process from which any HP 4062UX program has been executed. IC-CAP also locks the measurement bus only during a measurement, which is similar to “Implicit Locking” of the HP 4062UX.

Measurement Accuracy While the HP 4062UX performs certain error corrections for its 48- and 96-pin matrices, IC-CAP does not know about these internal parameters. Therefore the capacitance measurement accuracy is not specified when IC-CAP measures a capacitance through a switching matrix. However, performing a calibration at the matrix pins should reduce these errors introduced by the matrix.

NOTE HCU and HVU are not supported by HP 4062UX. Do not use HCU or HVU with HP 4062UX because their output range exceeds the maximum ratings of the switching matrix and may cause damage to the switching matrix.

Adding Instrument Drivers to IC-CAP

Many instruments can measure a device or a circuit. While IC-CAP supports major HP/Agilent instruments, other instruments manufactured by HP/Agilent or other vendors could be used for characterization work within IC-CAP. The Open Measurement Interface (OMI) is part of IC-CAP's open system philosophy that allows the addition of new instrument drivers.

NOTE Because creating new drivers requires using C++, you must obtain C++ software that will compile with both your operating system and with IC-CAP. To determine appropriate software media options and to obtain the most up-to-date part numbers, consult an appropriate pricing and configuration guide, or contact your sales representative.

This section provides information about OMI and the basic form of an OMI driver. Alternatives to creating a new driver are also addressed.

Using the Open Measurement Interface

The Open Measurement Interface enables you to add drivers for other instruments. User-added drivers can be full-featured, fully integrated, and indistinguishable from the Agilent-provided drivers. Like the Agilent-provided drivers, they are written using C++. OMI was designed to ensure that C Language programmers do not experience language barriers when creating new drivers.

Much of the work necessary to lay out the required code is performed by a tool kit comprised of *Driver Generation Scripts* described in *"Adding a Driver"* on page 194. These scripts also write all necessary code for the Instrument Options editors for a new driver, and all necessary code for the driver to be included in the Instruments Library shown in the Hardware Setup window.

The user is responsible for filling in the bodies of a set of functions that IC-CAP calls during measurements. A set of reusable software constructs is provided for accomplishing common programming tasks; refer to "Programming with C++" on page 219.

With the first version of the Open Measurement Interface (IC-CAP version 4.00), only GPIB based instrument I/O is formally supported.

OMI Guidelines

To use the Open Measurement Interface, the following qualifications are recommended.

- One year of C programming experience or recent completion of a good course in C. Familiarity with the use of *struct* data types in C (or *record* data types in PASCAL) is essential, because C++ classes build upon the *struct* concept.
- Experience writing code to control an instrument.
- Familiarity with the particular instrument's features and operation.
- A willingness to learn the details of the requests IC-CAP places on drivers, and the order in which they occur during principal operations: Measure, Calibrate, and Rebuild (instrument list).
- A copy of the C++ language system provided by your computer vendor, including manuals and a license.

Driver Development Concepts

The basic form of user-added drivers involves 1 file with declarations of data types and functions, and 1 file with implementations of functions. Because *Driver Generation Scripts* are provided, very few modifications to the declarations file are necessary; work is largely confined to the function implementations file. The separation of declarations and implementations is common practice, and

has been used with User C Functions. The source directory *$ICCAP_ROOT/src* is used for OMI compilation, just as it is for User C Functions.

The default source files for new drivers already contain example drivers:

- HP 4194: *user_meas.hxx* and *user_meas.cxx*
- HP 4140: *user_meas2.hxx* and *user_meas2.cxx*
- HP 54510: *user_meas3.hxx* and *user_meas3.cxx*

Unless you choose to add files to optimize your compilation process, the *$ICCAP_ROOT/src/Makefile* permits the make(1) command to create an up-to-date IC-CAP executable file with your latest modifications. This Makefile accounts for the distinct compilation needs of the C++ and C source files by invoking the appropriate compiler. By default, make(1) understands a *.cxx* suffix to mean C++ compilation, and *.c* to mean C compilation; the Open Measurement Interface follows this convention.

The process for building the shared libraries *libicuserc.<ext>* and *libicusercxx.<ext>* is demonstrated in Figure 5. It is not necessary to know the details; the make(1) command can perform the entire process (provided the *$ICCAP_ROOT/src/Makefile* is correct).

The user driver files, *user_meas.hxx* and *user_meas.cxx,* to which your driver is added by default, already contain an example driver. This keeps the facility simple but could slow your compilation. If you choose to add your code to other files, adjust the Makefile. Otherwise, do not modify the Makefile.

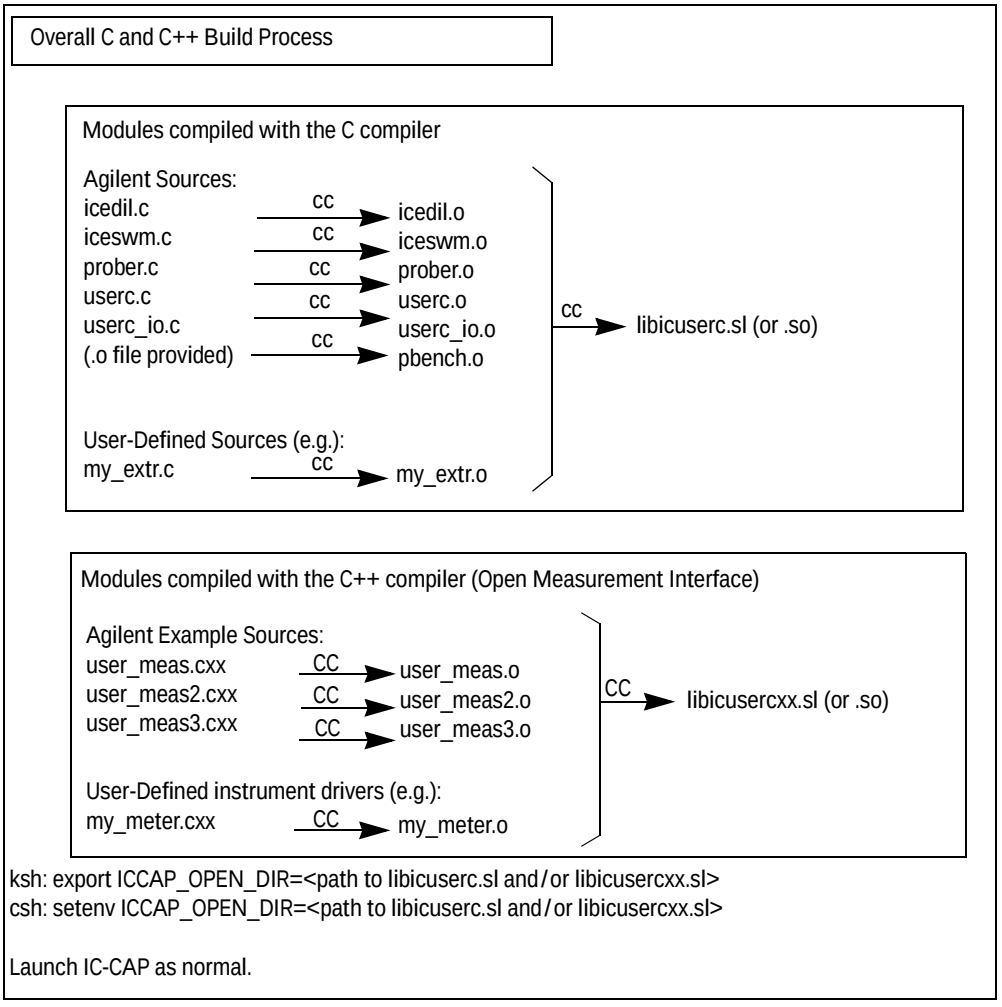

Figure 5 Flow Diagram for the User Build Process

NOTE

The *pbench.o* file is supplied since it is required to build the shared library. However, the source is not provided, so you cannot modify it.

Additional information is available online in example drivers, header files, and comments inside the code generated by the driver generation scripts.

Example Drivers Three example drivers HP 4194, HP 4140, and HP 54510 can be seen in the Instrument Library in the Hardware Setup window.

- Source files for the HP 4194 are *user_meas.hxx* and *user_meas.cxx*
- Source files for the HP 4140 are *user_meas2.hxx* and *user_meas2.cxx*
- Source files for the HP 54510 are *user_meas3.hxx* and *user_meas3.cxx*

The information provided by these example drivers should serve as valuable reference material for adding a new driver.

Header Files Files that are normally modified and re-compiled, *user_meas.hxx* and *user_meas.cxx*, use include (or header) files. The most important header files are *unit.hxx*, *user_unit.hxx*, *instr.hxx*, and *user_instr.hxx*. These files declare all of the *virtual* functions for each driver, and provide information to write (or avoid writing) each function.

Generated Code and Comments The driver generation scripts generate both code and comments. Generally, the comments state what each required function must return, when it is invoked, and its purpose. Code examples are often provided that you can use as the basis for the code you must provide. To access this information, run the scripts. For information, refer to "Driver Generation Scripts" on page 194.

Binary Byte Order

For information on transferring binary data between an instrument and IC-CAP, see the *README.byteorder* file in the source directory *$ICCAP_ROOT/src*. It contains important information with respect to the order of bytes in a multi-byte number.

Adding a Driver

The basic steps (details are provided in the paragraphs that follow) for adding a driver are:

1. Run the *Driver Generation Scripts*.
2. Fill in functions that control your instrument.
3. Inform IC-CAP of the new instrument type.
4. Build the IC-CAP executable file.
5. Debug the new driver.

Driver Generation Scripts

The driver generation scripts provide a framework of functions into which a user's driver code is placed.

mk_unit This script generates code for *units* in an instrument. In the case of an HP 4141, for example, there are 8 units, including 4 DC SMUs, 2 VS and 2 VM units. The HP 4194 example has just 1 unit, which is typical for a CV driver.

A transcript of the *mk_unit* session used for the HP 4194 driver is as follows:

```
$ mk_unit
Enter a name for the unit class for which you want code:
cvu_4194
Enter a name for the instrument class that will use this unit
class: hp4194
Enter the full name of the .hxx file that will declare hp4194
default: user_meas.hxx]:
Enter a name of twelve characters or less; the emitted code
will be appended to .cxx and .hxx files with this basename
[default: user_meas]:
Done. C++ code was added to user_meas.hxx and user_meas.cxx.
You should re-run mk_unit if more unit types are needed.
Otherwise, you probably need to run mk_instr now.
```

You must supply the name of 2 C++ *classes*. A *class* is a name for a user-defined C++ type and is like a struct in C. The *mk_unit* script uses your chosen class names throughout the generated code. In this example a unit class name (*cvu_4194*) was chosen to denote *CV Unit in a 4194*, and an instrument class name (*hp4194*) was chosen to reflect the name of the instrument. Try to select class names in the same style. Class names should be meaningful and specific, since this helps to avoid name collisions during compilation. Use, for example, a suffix relating

to the instrument or company. Do not hesitate to take advantage of the fact that the C and C++ compilers generally accept very long names. The use of long descriptive names helps prevent compilation or linking problems due to name collisions.

If the instrument has more than 1 kind of unit to drive, like the HP 4141, run *mk_unit* repeatedly. If it has several identical units, do not re-run *mk_unit*. Identical units can be taken into account after running *mk_instr*.

mk_instr This script generates code for instrument-wide functionality in a driver, such as calibration, self-test, and getting the instrument recognized during *Rebuild* (instrument list).

A transcript of the *mk_instr* session used for the HP 4194 driver is:

```
$ mk_instr
Enter the name of the instrument class for which you want
code: hp4194
Enter a name of twelve characters or less; the emitted code
will be appended to .cxx and .hxx files with this basename
[default: user_meas]:
Done. C++ code was added to user_meas.hxx and user_meas.cxx.
Now you can go take a look at user_meas.cxx, and start doing
the real work.
NOTE: in user_meas.cxx you may eventually need to add
#include statements to ensure that user_meas.cxx sees the
class declarations of any unit classes used by hp4194.
Disregard this if the necessary unit declarations appear at
the beginning of user_meas.hxx.(The mk_unit script should
generally have put them there.)
You WILL need to declare some units in the class declaration
of hp4194 in user_meas.hxx (see comments therein).
After running this script, you generally need to run
mk_instr_ui next.
```

This script requires the class name *hp4194* to be repeated again, exactly as it was entered in *mk_unit*. (In your own driver, use another class name besides *hp4194*, but repeat the same instrument class name when each script asks for it.)

The script mentions the need to *declare some units*, which is accomplished by manual edits to the *user_meas.hxx* file; for example

```
cvu_4194* cv_unit ;
```

accomplishes that for the HP 4194 driver in the file *user_meas.hxx* file. If the HP 4194 had 2 identical CV units available, this declaration might have been

```
cvu_4194* cv_unit_1 ;
cvu_4194* cv_unit_2 ;
```

mk_instr_ui This script generates code that fully implements the Instrument Options tables appearing in Setups that use the instrument driver. Within these tables, an IC-CAP operator can specify such things as Delay Time, Integration Time, and other instrument-specific options. Because this script completely writes out the necessary C++ code for this user interface functionality, it asks more questions than the previous scripts.

A transcript of the *mk_instr_ui* session used for the HP 4194 driver is:

```
$ mk_instr_ui
NOTE: valid types for editor fields are these:
{ real | int | char | boolean | string }
Enter the name of the instrument class for which you want UI
   code: hp4194
Enter a name of twelve characters or less; the emitted code
   will be appended to .cxx and .hxx files with this basename
   [default: user_meas]:
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Use User Sweep
Enter a type for editor field 'Use User Sweep' [h for help] :
   boolean
Enter an initial value for this field [ 0 or 1 ] : 0
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Hold Time
Enter a type for editor field "Hold Time" [h for help] : real
Enter the minimum legal value for this field: 0
Enter the maximum legal value for this field: HUGE
Enter a granularity value (for rounding this field; 0 for no
   rounding): 0
Enter an initial value for this field: 0
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Delay Time
Enter a type for editor field "Delay Time" [h for help] :
   real
Enter the minimum legal value for this field: 0
Enter the maximum legal value for this field: 3600
Enter a granularity value (for rounding this field; 0 for no
   rounding): 0
Enter an initial value for this field: 0
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Meas Freq
Enter a type for editor field "Meas Freq" [h for help] :
Sorry, "" is not a valid type.
The valid types are: { real | int | char | boolean | string }
Enter a type for editor field "Meas Freq" [h for help] : real
Enter the minimum legal value for this field: 100
Enter the maximum legal value for this field: 100e6
```

```
Enter a granularity value (for rounding this field; 0 for no
   rounding): 1
Enter an initial value for this field: 1e6
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Integ Time
Enter a type for editor field "Integ Time" [h for help] :
   char
This field will force the user to enter one character, from
   within a set of valid characters you will specify now.
Example set of valid characters: TFYN
Enter the set of character values that this field can take
   on: SML
Enter whether this field should force user input to
   uppercase [y/n]: y
Enter an initial value for this field: S
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Osc Level [.01-1Vrms]
Enter a type for editor field "Osc Level [.01-1Vrms]"
   [h for help] : real
Enter the minimum legal value for this field: .01
Enter the maximum legal value for this field: 1
Enter a granularity value (for rounding this field; 0 for no
rounding): 0 Enter an initial value for this field: .01
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Averages [1-256]
Enter a type for editor field "Averages [1-256]" [h for help]
   : int
Enter the minimum legal value for this field: 1
Enter the maximum legal value for this field: 256
Enter an initial value for this field: 1
Enter the label for an editor field (or enter a null string
   if no more fields are desired): Delay for Timeouts
Enter a type for editor field "Delay for Timeouts"
   [h for help] : real
Enter the minimum legal value for this field: 0
Enter the maximum legal value for this field: HUGE
Enter a granularity value (for rounding this field; 0 for no
   rounding): 0
Enter an initial value for this field: 0
Enter the label for an editor field (or enter a null string
   if no more fields are desired):
Done. All necessary C++ UI code was added to user_meas.hxx
   and user_meas.cxx.
```

From the nature of the questions in this script, this process defines an editor table for the instrument. The table offers some advanced features, such as constraining the type and the range of values that an operator can enter in each field.

Running the Scripts on Windows

To run the mk_instr, mk_unit, and mk_instr_ui scripts on Windows, first edit the file $ICCAP_ROOT/bin/icrun.bat. You must set ICCAP_ROOT accordingly by modifying the line:

```
SET ICCAP_ROOT=<Path to IC-CAP>
```

for example if you installed IC-CAP at `C:\Agilent\ICCAP_2006B`, edit the file to read

```
SET ICCAP_ROOT=C:\Agilent\ICCAP_2006B
```

Once this is set, simply change <*name*> below to mk_instr, mk_unit, or mk_instr_ui to run those scripts.

```
icrun <name>
```

Running the Scripts on UNIX

This section contains information about running the scripts, questions asked by the script, and the form of user responses.

- They are invoked as UNIX commands. Execute *cd $ICCAP_ROOT/src* unless you just want to experiment with the scripts in another directory like */tmp*. The *cd* command ensures that the code goes where the Makefile expects.
- Make backup copies of *user_meas.hxx* and *user_meas.cxx* before starting to use the scripts.
- The scripts are run in order: *mk_unit*, *mk_instr*, and *mk_instr_ui*. Running the scripts out of order may cause compilation errors when the compiler encounters types, classes, or variables before they are properly declared.
- All the scripts prompt you with a series of questions. The effect of the scripts is to write C++ code onto the end of the *user_meas.hxx* header file and the *user_meas.cxx* implementation file.

  Plan your response by reviewing the transcripts and comments presented previously for each script to avoid re-running the script. Multiple passes by the scripts could put declarations into *user_meas.hxx* more than once causing error messages from the scripts or a compile-time message such as *error 1113: class <some_class_name> defined twice*. To re-run the script, restore *user_meas.hxx* and *user_meas.cxx* to the same state as they appear on the IC-CAP product media.

- When providing real number values to *mk_instr_ui* supply values that a C compiler will accept. The engineering notation accepted by IC-CAP's PEL interpreter, such as *15meg*, or *2k*, is not accepted by the compiler. Examples of acceptable real numbers are:

  1.0
  10.5e6
  HUGE (a constant from */usr/include/math.h*)

- *granularity* as used in *real* fields, refers to a flexible rounding feature. For example, if your instrument has an option *Osc Level* for which the instrument has only 10 mV resolution, enter *granularity* as 10e-3. The Instrument Options editor then protects the IC-CAP operator from entering values the instrument can't support.

The scripts require you to fill in functions in *user_meas.cxx*. They also require a few minor adjustments in *user_meas.hxx*. These adjustments are:

- The instrument class should declare any units owned by the instrument. This is discussed under *mk_instr*.
- You may encounter compilation errors when unit and instrument functions attempt access to each other's data members, since this violates normal C++ access rules. For example, in *user_meas.cxx,* in hp4194::init_instr(), a function of the hp4194 class accesses a data member of the cvu_4194 class with this statement: *cv_unit -> oscillator_on = 1 ;*

  A typical compiler error message would be:

```
error 1299: init_instr() cannot access
cvu_4194::oscillator_on:
private member
```

  One way to remedy this is to let the unit and instrument class declare each other as *friends*. For example, the declarations

```
friend class cvu_4194 ;
```

  and

```
friend class hp4194 ;
```

in *user_meas.hxx,* permit the *hp4194* functions to access the *cvu_4194* data members, and vice-versa.

Filling in Necessary Functions

After running the scripts, you must write the body portions of the functions added to *user_meas.cxx.* This section provides hints to help you accomplish this.

For help filling in a function body, look at the declarations and functions generated by the scripts. These provide comments explaining the purpose, return value, and invocation time of each function.

Next look at the declarations and functions of the HP 4194 example driver. This section contains examples of code accomplishing required tasks. The following manual sections may also be helpful.

- "Programming with C++" on page 219
- "Order in Which User-Supplied Functions are Called" on page 229. Provides useful information about the sequence in which functions are invoked. Decisions must often be made about which function should perform particular instrument manipulations; these decisions can be aided by seeing when each function runs.
- "What Makes up an IC-CAP Driver" on page 207. Explains the functionality expected in areas such as *Calibration* and *Hardware Setup Operations.* The functions whose bodies you need to write are grouped in that section by functional category.

You may want to proceed in stages. For example, start with *Hardware Setup Operations* to demonstrate that Rebuild (instrument list) can find the instrument and display the driver and instrument in the Hardware window. Then implement the functions that support Measure. Address those functions that support Calibrate, if desired. During the time your driver is partially implemented, compiler warnings serve as a rough indication of functions not yet implemented.

The GPIB analyzer (Tools menu), and especially its macro features (described elsewhere in this chapter), are helpful when developing the appropriate sequence of commands to use with the instrument.

Making a New Instrument Type Known to IC-CAP

Running the *mk_instr* script makes a new instrument type known to IC-CAP. The code involves an *add_user_driver()* function call, placed in *user_meas.cxx* by the *mk_instr* script.

Creating a New Shared Library

After any series of edits to the source files, you must generate 1 or 2 new shared libraries to pick up the modified files. The shared library names are *libicuserc.<ext>* and *libicusercxx.<ext>* where *ext* is a platform-specific extension. Use the extension *.so* for Solaris. The library *libicuserc.<ext>* holds C code and is used to add user C functions. The library *libicusercxx.<ext>* holds C++ code and is used to add instruments. The default location of these files on SUN Solaris 2.X is *$ICCAP_ROOT/lib/sun2x*. When you issue the *make* command, you will create a local version of the same file that includes your modifications. By setting an environment variable, you can direct IC-CAP to use your new shared library instead of the default library.

To generate the new shared library:

1. Create a work directory for the source files (for example, *mkdir my_source*, and change it to (*cd my_source*).
2. Copy the set of source files from *$ICCAP_ROOT/src* to the new work directory (*cp $ICCAP_ROOT/src/* . *).
3. Use the *touch* command on the *.o files so that all *.c and *.o files appear to have been created at the same time (*touch *.o*). (This step is important for the *make* procedure.)

NOTE

If the drive you're copying to is NFS mounted, clock skews can result if the NFS drive's system has a slightly different system time than the local system. If you think this might apply to you, first, execute *touch* * then execute *touch* *.*o*. The first *touch* synchronizes all files to your local system's time; the following *touch* causes the *make* system to believe that all of the *.o* files were generated later than the source files, so it will not attempt to rebuild any unnecessary files.

4 Copy your source code to the working directory. Modify the function *add_users_c_funcs()* in *userc.c* to add your C functions to IC-CAP's list of functions, and/or modify the function *add_users_drivers()* in *user_meas.cxx* to add your drivers to IC-CAP's library of instrument drivers. Modify the *Makefile* to add your source code modules to the list of objects.

5 Issue the *make* command and debug any compiler errors.

6 Set the environment variable ICCAP_OPEN_DIR to point to the directory containing the *libicuserc.<ext>* or *libicusercxx.<ext>* file where *ext* is a platform-specific file extension (*ext* is *.so* on Solaris).

   Alternately, if you want to use the new files site wide, you can replace the original files (after copying to another name to preserve them) under $ICCAP_ROOT/lib/<platform>.

7 Start IC-CAP as usual.

Troubleshooting Compiler Errors

The definitive authority on compiler errors is your compiler documentation. This section offers assistance with some of the common messages you may encounter when compiling OMI drivers.

The message

```
CC: "user_meas.cxx", line 899: warning: outptr not used (117)
```

usually indicates that you have not yet filled in a function, with the result that the function is not using all of its arguments. In some cases the function may not use all of its arguments, so the message may not be important.

Resolution of the message

```
error 1299: some_unit_func cannot access
some_instr_class_name::some_member: private member
```

is discussed in "Running the Scripts on Windows" on page 197.

The message

```
CC: "user_meas.hxx", line 9: error: class x defined twice (1113)
```

indicates that the *Driver Generation Scripts* were probably run twice.

For help, refer to "Running the Scripts on Windows" on page 197.

Debugging

This section provides information about debugging driver code, after *iccap.new* has been compiled, including the xdb debugger and GPIB analyzer (Tools menu).

Using the xdb Debugger

The default Makefile arranges for debug information to be available after linking the executable file. This is done with the *-g* flag among the *CFLAGS* in the Makefile.

The debugger commands described in the following table should be tried in the order presented.

Table 50 Debugger commands for the xdb debugger

Command	Action
cd $ICCAP_ROOT/src	Changes directories. Debugging works best when the current directory contains the source files and the binary.
xdb iccap.new	Starts the debugger.
z 8 isr; z 16 isr ; z 18 isr	Tells the debugger not to interfere with 3 signals managed by other parts of iccap.new.

Table 50 Debugger commands for the xdb debugger

Command	Action
r bjt_npn.mdl	Runs iccap.new, specifying bjt_npn.mdl as a command line argument. If the debugger stops with a message such as *bad access to child process*, ignore it and enter c to continue.
BREAK or CTRL-C	Suspends iccap.new, to give further debugger commands. xdb does not execute commands unless iccap.new is suspended.
v user_meas.cxx	Enables you to view and edit a source file. This command is helpful for setting breakpoints.
td	Toggle display. Toggles the display mode between assembly code and C/C++. Use this if the preceding command displays assembly code on the screen, or if no code is displayed.
/hp4194::find	Searches forward (as in vi) to view the source for the function hp4194::find_instr().
v *nnn*	Enables you to view line *nnn* at the center of the screen where *nnn* is the line number you want to view.
b	Sets a breakpoint at the line currently centered on the screen. Sometimes the debugger chooses another nearby line, especially if the currently centered line is blank, or is only a declaration statement. When iccap.new resumes running, the debugger stops iccap.new whenever this line of code is about to be executed. You may set several breakpoints.
b *nnn*	Similar to the last command. Sets a breakpoint at line *nnn* where *nnn* is the line number you specify. Sometimes the debugger chooses another nearby line, especially if you chose a blank line, or a line with only a declaration statement.
S	Big step. Steps through 1 line of source code without stopping inside any procedure calls encountered.
Little	Like S, but this stops inside any debuggable procedure that is encountered while executing the line of code.

Table 50 Debugger commands for the xdb debugger

Command	Action
c	Continues execution of iccap.new.
Execute a menu function	To reach breakpoints in the driver code, use Measure, Calibrate, or Rebuild as appropriate. For help in making this choice, refer to "Order in Which User-Supplied Functions are Called" on page 229. Be sure that the function will actually be called if you want the breakpoint reached.
p address	When the debugger hits a breakpoint in a procedure, this command prints the value of an argument passed to the procedure, or a local variable in the procedure. In this example, the argument/variable is named address.
p address=23	To assign a new value to an integer variable named address, employ this special form of the p (print) command.
p *this\K	Prints the member data of the C++ object in whose member function the current breakpoint is located.

GPIB Analyzer (Tools menu) and IC-CAP Diagnostics

In addition to *xdb*, debugging capabilities are built into IC-CAP.

The GPIB analyzer (Tools menu) in the Hardware Setup window includes the following features.

- The *I-O Screen Debug On* menu selection can monitor all activity on the GPIB bus. Observe the GPIB commands and responses associated with your driver, as well as other IC-CAP drivers.
- The analyzer can be used for interactive I/O activities, to force an instrument state, poll the instrument, or test the effect of a command.
- Analyzer operations can be collected into a file for macros for rapidly prototyping the GPIB commands to be used in a driver. For more information about macro files of this sort, refer to "GPIB Analyzer" on page 783.

The generation of IC-CAP diagnostic messages can be activated by menu functions under *Tools* in the IC-CAP Main window.

Alternatives to Creating New Drivers

If you don't need an instrument driver to be as fully integrated as HP/Agilent-provided drivers, it may be worthwhile to consider controlling the instrument by means less formal than creating a driver using the Open Measurement Interface.

NOTE There is an important shortcoming with these suggestions. An IC-CAP measurement currently provides no mechanism for Program Transforms or Macros to be invoked at critical times in the *interior* of the measurement (for example, at the instant when DC bias levels have just been established by SMUs, and it is time for a main sweep instrument to stimulate the DUT and collect data). Use of the Open Measurement Interface overcomes such limitations.

- Use the *PRINT* statement in an IC-CAP Macro to direct commands to an instrument, when a suitable *device file* has been established using the *mknod* command.
- Use the functions listed with *USERC_write* and *USERC_read* in a Program Transform or Macro to provide limited instrument control. For descriptions of the User C functions in general, refer to Chapter 8, "IC-CAP Functions." For details and examples of the input/output functions, refer to Appendix H, "User C Functions."
- Rather than using the *Measure* menu selection directly, construct Macros in the following style to enclose the measurement between operations controlling other hardware:

```
! Steps 1, 2, and 3 are assumed to be implemented by PRINT.
! 1) Force next desired set point on temperature chamber.
! 2) Enable waveform generator.
iccap_func("/opamp/time_domain/positive_slew","Measure")
! 3) Disable waveform generator.
! One way to control the values desired for temperature and
! frequency is to access IC-CAP system variables.
```

What Makes up an IC-CAP Driver

In addition to measurement capabilities, each IC-CAP driver possesses other capabilities, such as the user interface functionality provided in *Instrument Options* folder and the ability to participate in *Input, Output and Setup Checking* prior to measuring. Each of these essential areas is discussed in this section. In each area, information is provided about the specific functions necessary to complete that part of a driver.

In the tables throughout this section, the prefix *unit::* means the class name(s) you provided for units when you ran the *mk_unit* script. The prefix *instr::* should be considered to mean the class name you provided for the instrument when you ran the *mk_instr* script. The column *Importance* indicates whether you typically need to write any code for the function. Because of the *inheritance* features of C++, you must often rely on inherited default functions. Functions important to write, typical return values, and other information can be determined from the comments for the function in *$ICCAP_ROOT/src/user_meas.cxx*.

Instrument Options

The Instrument Options folder provides a method for selecting certain instrument conditions for a measurement. Certain instrument conditions are separated into different groups of instrument options (rather than appearing in Input sweep editors) because they are highly instrument specific, and play no role in simulation. The options displayed in the Instrument Options folder typically vary with each setup that participates in the measurement involving a particular instrument.

The Driver Generation Scripts, described in *Procedure for Adding a Driver*, can write all the C++ code that is necessary to establish appropriate instrument options tables for a new driver. The driver generation script named *mk_instr_ui* prompts for the desired contents of the instrument options tables, after which it proceeds to generate the necessary declarations and implementations in

C++. The generated code will contain data structures in which options are stored, as well as the user interface linkages that display the options for editing.

Input, Output and Setup Checking

When you initiate *Measure* or *Calibrate* for a Setup, IC-CAP first verifies the validity of the measurement Setup. This permits many operator errors to be detected and reported before IC-CAP undertakes instrument I/O.

IC-CAP performs the following 3 kinds of checks:

- Checks Input (Sweep) specifications; for example, does a Start or Stop value exceed the instrument's range?
- Checks Output specifications; for example, can the instrument measure the type of data desired, such as capacitance?
- Checks overall Setup structure; for example, is there more than 1 time or frequency sweep being requested?

Table 51 describes the functions related to input (sweep) checking.

Table 52 shows a summary of the supported Input (Sweep) modes in IC-CAP. The column *Character Used in Driver Functions* shows the character passed when an Input Mode is passed to a function, such as *unit::can_source*.

Table 53 describes the functions related to output checking.

Table 54 shows a summary of the supported Output modes in IC-CAP. The column *Character Used in Driver Functions* shows the character passed when an Output Mode is passed to a function, such as *unit::can_measure*.

Table 51 Functions for Input Checking

Function Name	Purpose	Importance
instr::use_second_sweep	tells if unit has 2 internal sweeps	default usually OK

Table 51 Functions for Input Checking (continued)

Function Name	Purpose	Importance
unit::can_source	tells if unit can source a given Mode	important
unit::can_source_vs_time	tells if unit can source time-domain signals	important for pulse generators
unit::check_bias_swp	reserved for future use	default is OK
unit::check_sweep	lets unit check/preview Input data set	important
unit::check_sync	checks sync sweep spec.	important if implementing sync sweeps

Table 52 IC-CAP Input (Sweep) Modes

Character Used in Driver Functions	Meaning
V	Voltage
I	Current
F	Frequency
T	Time
P	Parameter
U	User (refer to "User-Defined Input and Output Modes" on page 211)

Table 53 Functions for Output Checking

Function Name	Purpose	Importance
unit::can_measure	tells if unit can measure a given Mode	important
unit::can_measure_vs_time	tells if unit can measure time-domain signals	important for oscilloscopes

Table 53 Functions for Output Checking (continued)

Function Name	Purpose	Importance
unit::check_out	lets unit check/preview Output data set	important if measures multiple data sets

Table 54 IC-CAP Output Modes

Character Used in Driver Functions	Meaning
V	Voltage
I	Current
C	Capacitance
G	Conductance
T	Time Domain Pulse Parameter (like RISETIME)
S, H, Z, Y, K, A	Two-Port
U	User (refer to "User-Defined Input and Output Modes" on page 211)

Setup checking is performed primarily by logic embedded in IC-CAP. A limited amount of the checking is accomplished with user-supplied functions. The following table describes the user functions related to overall Setup checking.

Table 55 Functions for Overall Setup Checking

Function Name	Purpose	Importance
instr::find_instr	checks GPIB for instrument	necessary
instr::find_units	locates optional units	default usually OK
instr::set_found	remembers instrument was found; could set internal flags concerning presence of optional hardware modules	default usually OK

Table 55 Functions for Overall Setup Checking (continued)

Function Name	Purpose	Importance
instr::use_second_sweep	tells if unit has 2 internal sweeps	default usually OK
unit::bias_compatible	checks if this unit can tolerate signal or bias from another unit	could potentially save fuses.
unit::can_do_second_sweep	tells if another sweep and unit can be an internal sweep secondary to the sweep for this unit	default is OK

User-Defined Input and Output Modes

Mode *U is a* reserved user-defined mode that allows some flexibility for safely checking any new signal modes to be sourced or measured. This feature is for situations where it is not practical or safe to use existing Input or Output modes (such as voltage or capacitance).

The following considerations apply:

- Units associated with existing drivers are likely to reject *U*. For example, a HP 4141 VM unit will not force or measure *U*. In such a case the measurement is disallowed. (It does not make sense for the IC-CAP HP 4141 driver to try to force or measure *U-Mode* data, since it does not know what *U-Mode* means.)
- The unit functions associated with the new driver can enforce any desired policy for a *U-mode* Input or Output, as well as the other Input and Output Modes.
- With a *U-Mode* Input or Output in an IC-CAP Setup, do not expect the *Simulate* menu function to work on that Setup.

Calibration

Calibration functions are associated with the instrument, not its units. To perform calibration procedures initiated from the IC-CAP program, implement the functions shown in the following table.

Table 56 Functions for Calibration

Function Name	Purpose	Importance
cal_possible	tells if the other 2 functions do anything	These functions are necessary if IC-CAP is to calibrate the instrument.
do_cal	downloads Setup, leads operator through calibration procedure	
recall_n_chk_calib	activates calibration during Measure; checks sweep	

Several of the functions required for *Measure* are also used during *Calibrate*. Refer to "Order in Which User-Supplied Functions are Called" on page 229 in this chapter for a list of functions called during *Calibrate*.

Storage is provided in the *instr_options* class for limited calibration data for a particular instrument in a particular Setup. The *instr_options* class is declared in *instr.hxx*.

The data members in *instr_options* for holding calibration results are:

- *String cal_data ; //*
  declare your own data if String is not an appropriate type
- *calib_status last_cal_status ; //*
  calib_status is an enumeration with these possible values:
  - *CAL_OK*
  - *CAL_ERROR*
  - *CAL_ABORTED*
  - *CAL_NEVER_DONE*

Set *calib_status* during *do_cal()* and test it during *recall_n_chk_calib()*. Recall that *cal_possible()* and *do_cal()* are invoked (in that order) during *Calibrate,* while *recall_n_chk_calib()* is later called during *Measure,* with the purpose of enabling the desired calibration set.

Derived from the class *instr_options* (declared in *instr.hxx*) is *user_instr_options,* declared in *user_instr.hxx*. For the new driver, a further derived class will have been declared in *user_meas.hxx* by the *mk_instr_ui* script. The section *Class Hierarchy for User-Contributed Drivers* clarifies the relationships of these classes.

The class in *user_meas.hxx* that is derived from *user_instr_options* is an appropriate place to declare additional calibration data the workstation should retain, because a distinct *object* (or *data structure*) of this type exists in every situation where distinct instrument calibration data might be needed. In other words, an instrument has a distinct *user_instr_options* object in every Setup where the instrument is used. For the example of the HP 4194 driver, such data (if any) would be declared in the class named *hp4194_table* in *user_meas.hxx*. You might declare several *double* numbers, to keep a record of sweep limits that were in effect at the time of Calibrate, so that they can be verified during Measurement. (With many instruments, calibration is not valid unless measurements employ the same sweep limits that were in effect during calibration.)

NOTE To simplify an initial pass at implementing calibration, do not declare additional data structures for remembering sweep parameters, and do not perform much verification during *recall_n_chk_calib()*.

If you choose to declare additional calibration-related data in the class derived from *user_instr_options,* it is possible for this data to be archived and re-loaded with IC-CAP Model(*.mdl*), DUT(*.dut*), and Setup(*.set*) files. Note that the

archiving of user-defined calibration data is an advanced feature that most implementations can probably avoid considering.

To archive user-defined calibration data, your class derived from *user_instr_options* must redeclare and implement 2 virtual functions. These functions are *read_from_file* and *write_from_file,* declared for the class *instr_options*, in the file *instr.hxx*. When called, these functions receive an open *stdio* FILE*, which provides read or write access to the IC-CAP archive file at the appropriate time during a *Read From File* or *Write to File* menu function.

Measurement: Initialization, Control and Data Acquisition

The functions in this area perform the real work of the instrument driver; this area accounts for the largest number of functions present in each driver.

Initialization functions are listed in the following table.

Table 57 Initialization Functions

Function Name	Purpose	Importance
instr::init_instr	downloads information from the Instrument Option Table	necessary
instr::reset_instr_info	clears flags in driver, refer to instr.hxx	default usually OK
instr::reset_outptrs	nulls out output data set pointers, refer to instr.hxx	default usually OK
instr::zero_supplies	puts instrument to safe state, turns off sources	necessary
unit::enable_output	enables any output unit needing explicit enabling (refer to *user_meas.cxx*)	necessary with some instruments, such as the HP 4141
unit::init_unit	reserved for future use	default is OK

Table 57 Initialization Functions (continued)

Function Name	Purpose	Importance
unit::reset_inassign	reserved for use by 4142 and 4145	default is OK
unit::reset_outassign	reserved for use by 4142 and 4145	default is OK
unit::set_2_internal_sweeps	downloads specifications for 2 nested internal sweeps	default usually OK
unit::set_internal_sweep	downloads specifications for internal sweep	necessary
unit::set_sync	downloads specifications for sync sweeps	default usually OK
unit::zero_supply	puts unit to safe state, suppresses bias and so on	necessary, if the unit can source bias or other signal

Control and data acquisition functions are shown in Table 58.

Because many of the functions in this category must perform non-trivial work, such as instrument communication and error reporting, refer to "Programming with C++" on page 219, where such operations are explained. The examples for the cvu_4194 member functions and the hp4194 member functions in *user_meas.cxx* are also helpful.

A few of the functions in this area are provided for the support of a particular instrument, for example, the HP 4145. The intermediate classes *user_unit* and *user_instr* do not redeclare some of these low-usage functions, though their declarations are inherited from the *unit* and *instr* classes, so they could be used in a new driver if needed. For example, *instr::use_second_sweep()* is re-declared and used only by the HP 4145 driver.

Table 58 Control and Data Acquisition Functions

Function Name	Purpose	Importance
instr::copy_outds	does delayed data set stuffing (refer to *instr.hxx*)	default usually OK
instr::fill_outds	similar to copy_outds (refer to *instr.hxx*)	default usually OK
instr::get_outptr	gives pointer to Output data set	default usually OK
instr::keep_mdata	keeps 1 data point	default is OK
instr::out_count	tells number of output pointers in instr class	default usually OK
unit::can_do_second_sweep	tells if 2 internal sweeps OK (refer to *unit.hxx*)	default is OK
unit::define_channel	reserved for 4145	default is OK
unit::enable_sync	reserved for future use	default is OK
unit::fill_outds	any data this unit has kept internally, or in data structures of the instrument or unit driver, that belong in outptr, should be saved there now (refer to *user_meas.cxx*)	default usually OK
unit::get_data	gets data from the instrument (Refer to *user_meas.cxx*)	necessary
unit::get_int_bias	reserved for future use	default is OK
unit::get_scalar_data	reserved for 54120 series	default is OK
unit::list_chan_num	reserved for 4142	default is OK
unit::list_output_name	reserved for 4145	default is OK
unit::meas_err	used by some drivers to make error messages	default is OK

Table 58 Control and Data Acquisition Functions (continued)

Function Name	Purpose	Importance
unit::set_bias	forces a bias value	necessary for user sweep
unit::set_data_out	reserved for 4145	default is OK
unit::set_scalar	reserved for 54120 series	default is OK
unit::source_const_unit	reserved for 4145	default is OK
unit::source_unit	reserved for 4145	default is OK
unit::trigger	directs a unit to perform the measurement specified earlier via *set_internal_sweep*	necessary
unit::turn_chan_OFF	reserved for 4145	default is OK
unit::wait_data_ready	allows the instrument to finish measurement before trying to get data after trigger. In the *cvu_4194* code, this wait is accomplished in the trigger function.	default usually OK
unit::wait_delay_time	implements Delay Time prior to a spot measurement. Refer to cvu_4194 case in *user_meas.cxx*.	necessary
unit::wait_hold_time	implements Hold Time prior to a User Main Sweep. Refer to cvu_4194 case in *user_meas.cxx*.	necessary

Hardware Setup Operations

The Hardware Setup functions, listed in Table 59, are used in the following operations:

- Maintaining lists of instruments and units

  - Adding and deleting instruments
  - Maintaining the unit table, including the addition of entries due to newly added instruments
  - The *Rebuild* (instrument list) function
- Self-testing the instruments
- Polling the instruments

Table 59 Hardware Setup Functions

Function Name	Purpose	Importance
instr::addl_addr_label	reserved for 8510 and 8753	default is OK
instr::build_units	creates unit objects. Refer to *hp4194::build_units* in *user_meas.cxx*.	necessary
instr::find_instr	checks GPIB for instrument	necessary
instr::find_units	locates optional units	default usually OK
instr::get_addl_addr	reserved for 8510 and 8753	default is OK
instr::get_ID	gets instrument ID string. Refer to *user_meas.cxx*.	necessary
instr::get_unit_by_name	finds a unit in the instrument	default is OK
instr::instr *	initializes data members of instrument object	necessary
~instr::instr *	cleans up members of instrument object	necessary
instr::read_units	reserved for 4142	default is OK
instr::rebuild_units	reserved for 4142	default is OK

Table 59 Hardware Setup Functions (continued)

Function Name	Purpose	Importance
instr::set_found	remembers that instr found; may test and set internal flags concerning presence of optional hardware modules	default usually OK
instr::test_instr	supports the Run Self Tests menu function in the Hardware Setup window	default is OK (no self-test)
instr::unit_count	tells how many units the instrument has	necessary
instr::units_configurable	reserved for 4142	default is OK
instr::write_units	reserved for 4142	default is OK
unit::unit *	initializes data members of unit object	necessary
~unit::unit *	cleans up members of unit object	necessary

* denotes a constructor or destructor function for which the actual name is the unit or *instr* class name chosen when the mk_unit and mk_instr scripts were run. For example, hp4194::hp4194, in user_meas.cxx.

Programming with C++

This section provides examples of code for common Open Measurement Interface programming tasks.

- Access to Inputs (Sweeps) and Outputs
- Error and Warning Messages
- Reading from an Instrument
- Serial Poll of an Instrument
- String Handling
- Time Delay
- User Input with a Dialog Box

- Writing to an Instrument

Access to Inputs (Sweeps) and Outputs

In *user_meas.cxx* the function *cvu_4194::check_sweep* demonstrates how to determine sweep properties like *Mode* (V, for example), *Type* (LOG, for example), compliance, and start and stop values.

IC-CAP computes all necessary step values. Do not attempt to compute them from start, stop, and so on, because simulations will use the values IC-CAP computes. Instead, access individual sweep steps with the *get_point* function.

Following are statements from *cvu_4194::check_sweep* that determine sweep properties and get sweep values. These statements are isolated examples and are not necessarily to be used in the order shown.

```
int cvu_4194::check_sweep(sweep* swp)
// header of the function used  here
sweep_def *swpdef = swp->get_sweep_def();
// a sweep uses sweep_def for values
switch(swpdef->get_esweep_type())
// to see if it's CON, LOG, LIN, ...
compval = swp->get_compliance();
// compliance
case CON:
   val1 = ((con_sweep *)swpdef)->get_value();
// value of CON sweep
case LIN:
   val1 = ((lin_sweep *)swpdef)->get_start();
// start value of LIN sweep
   val2 = ((lin_sweep *)swpdef)->get_stop();
// stop value
((lin_sweep *)swpdef)->get_stepsize()
// step size
// next 2 are taken from cvu_4194::set_internal_sweep:
linswp = (lin_sweep*)swpdef ;
// to enable lin_sweep functions
numpoints = linswp -> get_num_points();
// number of points
if (swp->get_sweep_order() == 1)
// sweep order; 1 => main sweep
switch (swp->get_mode())
// Mode: 'V', 'I', 'F', ...
swp->get_size()  // Number of points
swp->get_point(step_num)
// get one point (indexed from 0)
```

The class named *sweep* is declared in *sweep.hxx*. Using a sweep often involves using functions it *inherits* from the class *ds* (data set), declared in *ds.hxx*. The function *get_point* is an example of a function inherited from *ds*. The *sweep_type* class is in *sweep_type.hxx*.

To save measured data to an IC-CAP Output data set, employ the style in *cvu_4194::get_data*:

```
dsptr -> keep_point (index++, datapoint, DATA_MEAS);
// datapoint is a double
```

In the example, *dsptr* points to a *ds* object. The class *ds* declares other forms of the *keep_point* function in *ds.hxx*. These can store complex or 2-port matrix data into the Output data set.

Error and Warning Messages

The IC-CAP error box appears after a measurement, displays one or more messages, and must be dismissed by clicking OK if you make one or more statements such as

```
errbox << "ERROR: HP4194 unsupported internal sweep type."
<< EOL;
errbox << "ERROR: HP4194 sweep produced " << num_points_kept
<< "when" << swp_num_points << " were requested" << EOL ;
```

Warnings are displayed in the Status window:

```
cerr << "WARNING: HP4194 frequency rounded up to 100Hz" << EOL ;
```

The objects *errbox* and *cerr* accept any number of arguments, of various types, including *double, String, char*, int,* and *char*. Separate them with << .

Reading from an Instrument

The *user_meas.cxx* file demonstrates 2 styles. Writing and reading are done with separate calls. In *hp4194::get_id* a readstring function is used as follows:

```
stat=ioport->readstring(ad,id_buf,255);
// below is the code needed to call readstring from
// a unit class function
stat=get_io_port()->readstring(ad,id_buf,255);
// because the instrument owns and maintains the ioport
// object, the unit gets it this way before using it
```

The first argument above is the GPIB address. The *id_buf* argument is a buffer guaranteed to be adjusted by readstring to hold 255 bytes, if the read produces that many.

A function is also provided to write a query and then read an answer:

```
if ( ioport->write_n_read(addr,"MKRB?", urbuf, 80) == -1 )
```

The first argument above is the GPIB address. The second argument is a char* to be written. The third argument is a buffer guaranteed to be adjusted by readstring to hold 80 bytes, if the read produces that many.

The above functions are 2 of many available for an *hpib_io_port*. Complete declarations of its functions are in *io_port.hxx*.

Serial Poll of an Instrument

The following functions are 2 of many available for an *hpib_io_port*. Complete declarations of its functions are in *io_port.hxx*.

Serial polling is done as follows:

```
int status_byte = ioport->spoll(addr);
// this example not from user_meas.cxx
int status_byte = get_io_port()->spoll(addr);
// call from a unit function
```

To wait for a particular serial poll bit:

```
// from cvu_4194::zero_supply:
hpib_io_port *ioport = get_ioport();
// bit-weight 1 below is to await 'measurement complete bit'
if ( ioport -> poll_wait(addr, 1, 0, 10.0) == -1 )
```

The arguments are: GPIB address, bit-weight to wait for, a flag reserved for future use, and maximum time that *poll_wait* should try (10 seconds).

String Handling

C++ offers a substantial improvement over C for handling *String* type data. In the file *String.h* a number of *String* functions are declared. The following code demonstrates several.

```
String str_hello = "hello" ;                      // declare and initialize a string
String str_world ;                                // just declare
str_world = "world" ;                             // assignment
String hello_world = str_hello + " " + str_world ;// concatenation
errbox << hello_world + "0 ;                      // writing to errbox
if ( "hello world" == hello_world )               // test for equality
String instr_cmd = "*RST" ;                       // initialize for next statement:
if ioport->writestring(addr,instr_cmd) == -1 )    // String to instrument
```

In the final example, a *char** is expected by *writestring*, and C++ automatically extracts it from the *String*. Do not pass a *String* to *printf* or *scanf*. The declarations of these functions in */usr/include/stdio.h* use the ellipsis notation (...), so C++ does not know that a *char** should be passed to them.

Time Delay

An example of a time delay is:

```
delay ( 10E-3 ) ;   // 10 millisecond delay
```

User Input with a Dialog Box

A number of functions for this purpose are declared in *dialog.hxx*. Examples to get data from dialog boxes are:

```
// These use the versions of get_double and get_String that
//   each take 3 arguments.
double double_result ;
String String_result ;
int ok_or_cancel ; // 0 => OK pressed by user, and -1 => CANCEL
ok_or_cancel = get_double ("Give a double:",default_dbl_val,&double_result);
ok_or_cancel = get_String ("Give a string:",default_string,&String_result);
```

Writing to an Instrument

An example of writing to an instrument is:

```
if ( ioport->writestring(addr,"TRIG") == -1 )
// cvu_4194::zero_supply
```

The arguments are the GPIB address and a *char** string to send. You can also write a query and read a response with 1 call, *write_n_read*, discussed in *Reading from an Instrument*. *Writestring* and *write_n_read* are 2 of many functions available for an *hpib_io_port*. Complete declarations of its functions are in *io_port.hxx*.

Syntax

This section provides help with reading the IC-CAP source code in *user_meas.hxx, user_meas.cxx,* and the various include files. Follow the example code in *user_meas.hxx* and *user_meas.cxx* when implementing a new driver.

NOTE

For best results when using the *vi* editor to browse the source files, execute the command *:set tabstop=3*

The C++ language introduces several keywords to help understand OMI programming, for example, *class, new, delete,* and *virtual.* Terms that are peculiar to OMI programming, for example, *Measurer, sweep type, sweep order, main sweep, internal sweep, user sweep, unit function,* and *instrument data,* are used in this chapter and in the source files.

Function declarations in C++ use the improved *function prototypes* of ANSI/C. For example,

```
int mult_by_2(int input);
// style for forward declaration int y=2 ;
int y = 2 ;
int x = mult_by_2(y) ; // example of invocation
int mult_by_2(int input)
// style for implementation (SAME AS DECLARATION)
{
   return 2*input ;
}
```

This is an area of incompatibility with original (Kernighan and Ritchie) C. However, it is easier to read, and write, and is the emerging new standard. It also gives the compiler information with which function call argument lists can be checked, saving run-time aggravation.

Sometimes in class declarations you will see the function body present:

```
const char *class_name()
// this code from user_meas.hxx
{ return "cvu_4194" ; }
```

These cases are called *inline* functions. They behave like normal functions, but the C++ compiler emits code inline, without normal function call overhead. For short functions this reduces both execution time and code size.

New Symbols and Operators

This section defines new symbols and operators in C++.

// A pair of slashes introduces an end-of-line comment. (/* and */ can still be used for C-style comments.)

& Appearing after a type name or class name, & usually indicates that an argument to a function is passed by reference. Although C can pass arguments by address, the C++ notion of reference arguments eliminates many error-prone uses of * (pointer de-reference) and & (address) operators used with pointer handling in C. In the following example, the called function increments the callers variable:

```
// 'input' passed by reference:
void increment(int& input) {
   input++ ;   // need not use *input
}
int x=3;
increment(x); // Need not pass &x
// Now x is equal to 4
```

object. member_function( ) In C, the . operator is used to access data members in a struct object. In C++, . is also used to access (execute) function members.

ptr_to_object->member_function() In C, the -> operator is used to access data members in a struct object to which one holds a pointer. In C++, -> is also used to access (execute) function members of a class type object to which you hold a pointer.

Class Hierarchy for User-Contributed Drivers

The diagram in the following figure depicts the relationships of the classes that are of principle interest to a user creating a driver. The arrows without labels indicate pointers held in the objects.

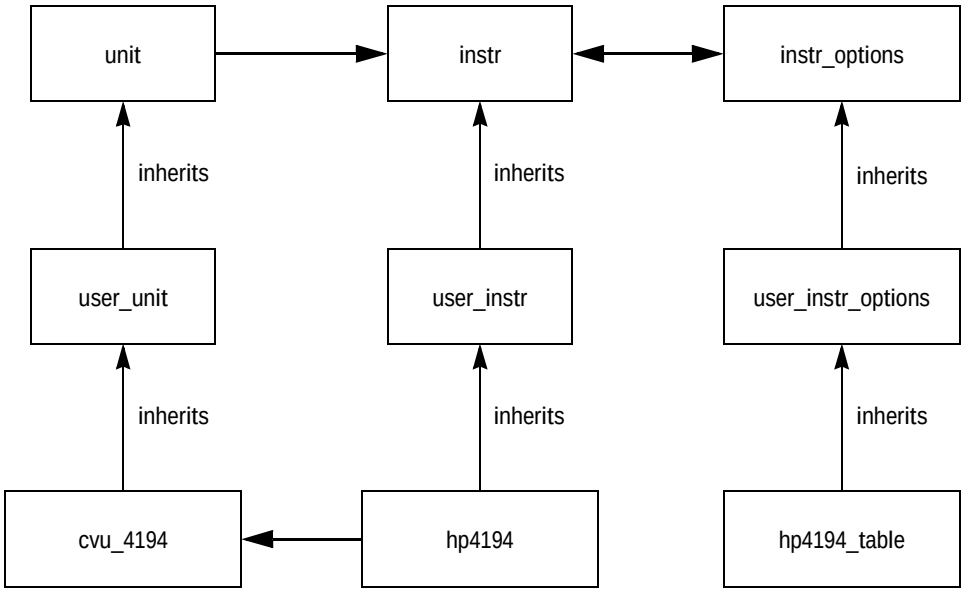

Figure 6 Classes Involved in the HP 4194 Example of a User Driver

At the top of the hierarchy are classes named *unit*, *instr*, and *instr_options*. All instrument drivers in IC-CAP consist of classes *derived* from these 3 classes. When Agilent Technologies adds a driver to IC-CAP, one new class is derived from *instr*, one or more new classes are derived from *unit*, and one new class is derived from *instr_options*. The process of deriving new classes from these base classes permits the new driver to efficiently reuse generic

functionality present in the base classes, while also introducing new code where necessary to accommodate the specialized needs of the new instrument.

The division of a driver into *unit, instr,* and *instr_options* components helps modularity. Generally, the role of each of these parts is as follows:

- instr - manages operations associated with the whole instrument, such as self-test and initialization.
- instr_options - presents a user interface for and stores the values of options unique to each Setup in which an instrument is used. For example, the option *Use User Sweep* determines whether an instrument does or does not use its internal sweep capability during measurement in a particular Setup.
- unit - manages operations on a single SMU for example, in the case of a DC analyzer, or on a single oscilloscope input, in the case of a multi-channel digitizing oscilloscope like the 54120 series. Operations undertaken at this level include the application of DC and other signals to the DUT, as well as the acquisition of the measured data.

Intermediate in the hierarchy are 3 classes named *user_unit, user_instr,* and *user_instr_options.* These serve the following purposes:

- Hide any virtual functions of unit and instr that are unlikely to be necessary to override in new driver classes. This allows the critical function declarations to be concentrated in one location, with comments close at hand.
- Introduce new member functions provided for Instrument Options management or for convenience.

At the bottom of the hierarchy are examples of classes introduced by the *Driver Generation Scripts*. When a user adds a driver to IC-CAP, the *Driver Generation Scripts* add a class derived from *user_instr*, one or more classes derived from *user_unit,* and a class derived from *user_instr_options.* The class derived from *user_instr_options,* which is *hp4194_table* in the example driver, is completely declared

and implemented when the user runs the *mk_instr_ui* script. In other words, a programmer using the Open Measurement Interface need not become involved with any coding that pertains to this user interface component of the driver. The programmer also does not need to provide *declarations* for any new classes needed for the driver, since these are completely written out when the driver generation scripts *mk_unit, mk_instr,* and *mk_instr_ui* are run. However, the programmer is required to fill-in the *implementations* of several functions that ultimately perform the work done by the driver.

Order in Which User-Supplied Functions are Called

Table 60 through Table 63 illustrate the following 3 essential instrument operations:

- Rebuild (instrument list)
- Calibrate
- Measure

These tables are representative of a typical order of invocation. Some functions may be used more than once, particularly since *Measure* involves looping through different bias levels. The column *Function Category* indicates the location of further information about the function in "What Makes up an IC-CAP Driver" on page 207. Other valuable information is located in the comments for each function, provided in *user_instr.hxx, user_unit.hxx, user_meas.hxx,* and *user_meas.cxx*.

During Rebuild

During this operation, the Hardware Manager locates addresses that respond to a serial poll. At each such address, available drivers determine if they own the instrument, until 1 driver succeeds. They try in the order shown in the Instrument Library list. Note that unless *find_instr()* is successful, none of the ensuing functions are called.

The functions called during *Rebuild* (instrument list) are shown in the following table.

Table 60 Functions Called During Rebuild (instrument list)

Function Name	Function Category
get_addl_addr	Hardware Editor Operations
addl_addr_label	
find_instr	
units_configurable	
rebuild_units or build_units	
find_units	
set_found	
unit_count	
get_unit	

During Calibrate

During this operation the Measurer initiates calibration procedures for each instrument in a Setup that has calibration supported by IC-CAP.

The functions called during *Calibrate* are shown in the following table.

Table 61 Functions Called During Calibrate

Function Name	Function Category
instr::find_instr	Setup Checking
unit::get_int_bias	Control and Data Acquisition Functions
unit::can_source	Checking of Inputs
unit::can_source_vs_time	Checking of Inputs
unit::can_measure_vs_time	Checking of Outputs
unit::can_measure	Checking of Outputs
unit::bias_compatible	Setup Checking

Table 61 Functions Called During Calibrate (continued)

Function Name	Function Category
unit::check_sweep	Checking of Inputs
unit::check_sync	Checking of Inputs
instr::cal_possible	Calibration
instr::find_instr	Setup Checking
instr::do_cal	Calibration

During Measure

This operation undertakes a potentially complex series of operations on the instruments used by a Setup. The exact functions called vary, depending on whether calibration is available for particular instruments, and whether the main sweep instrument operates in an internally swept fashion, or in a stepped/spot-mode fashion (the case when the instrument option *Use User Sweep* is set to *Yes* for the main sweep instrument).

The functions called during *Measure* are shown in Table 62 (user main sweep) and Table 63 (internal main sweep).

Table 62 Functions Called During Measure (with User Main Sweep)

Function Name	Function Category	Notes
instr::find_instr	Setup Checking	
instr::find_units	Hardware Editor Operations	
instr::set_found	Hardware Editor Operations	
unit::get_int_bias	Control and Data Acquisition Functions	
unit::can_source	Checking of Inputs	
unit::can_source_vs_time	Checking of Inputs	

Table 62 Functions Called During Measure (with User Main Sweep)

Function Name	Function Category	Notes
unit::can_measure_vs_time	Checking of Outputs	
unit::can_measure	Checking of Outputs	
unit::bias_compatible	Setup Checking	
instr::reset_instr_info	Initialization	
unit::check_sweep	Checking of Inputs	
unit::check_sync	Checking of Inputs	
instr::reset_outptrs	Initialization	
unit::check_out	Checking of Outputs	
unit::can_do_second_sweep	Control and Data Acquisition Functions	
instr::cal_possible	Calibration	
instr::recall_n_chk_calib	Calibration	
instr::init_instr	Initialization	
instr::zero_supplies	Initialization	
BEGIN BIAS LOOP		Loop to END BIAS LOOP
unit::set_bias	Control and Data Acquisition	
unit::enable_output	Initialization	
unit::set_scalar	Control and Data Acquisition	
BEGIN USER MAIN SWEEP LOOP		Loop to END MAIN SWEEP
unit::wait_hold_time	Control and Data Acquisition	
unit::set_bias	Control and Data Acquisition	

Table 62 Functions Called During Measure (with User Main Sweep)

Function Name	Function Category	Notes
unit::set_sync	Control and Data Acquisition	
unit::wait_delay_time	Control and Data Acquisition	
unit::get_data	Control and Data Acquisition	
unit::get_scalar_data	Control and Data Acquisition	
END MAIN SWEEP LOOP		
END BIAS LOOP		
instr::zero_supplies	Initialization	
unit::fill_outds	Control and Data Acquisition	

Table 63 Functions Called During Measure (with Internal Main Sweep)

Function Name	Function Category	Notes
instr::find_instr	Setup Checking	
instr::find_units	Hardware Editor Operations	
instr::set_found	Hardware Editor Operations	
unit::get_int_bias	Control and Data Acquisition Functions	
unit::can_source	Checking of Inputs	
unit::can_source_vs_time	Checking of Inputs	
unit::can_measure_vs_time	Checking of Outputs	
unit::can_measure	Checking of Outputs	
unit::bias_compatible	Setup Checking	

Table 63 Functions Called During Measure (with Internal Main Sweep)

Function Name	Function Category	Notes
instr::reset_instr_info	Initialization	
unit::check_sweep	Checking of Inputs	
unit::check_sync	Checking of Inputs	
instr::reset_outptrs	Initialization	
unit::check_out	Checking of Outputs	
unit::can_do_second_sweep	Control and Data Acquisition Functions	
instr::cal_possible	Calibration	
instr::recall_n_chk_calib	Calibration	
instr::init_instr	Initialization	
instr::zero_supplies	Initialization	
BEGIN BIAS LOOP		Loop through END BIAS LOOP below
unit::set_bias	Control and Data Acquisition	
unit::enable_output	Initialization	
unit::set_scalar	Control and Data Acquisition	
unit::enable_sync	Control and Data Acquisition	
unit::set_2_internal_sweeps	Initialization	
unit::set_internal_sweep	Initialization	
unit::set_bias	Control and Data Acquisition	
unit::set_sync	Control and Data Acquisition	
unit::trigger	Control and Data Acquisition	

Table 63 Functions Called During Measure (with Internal Main Sweep)

Function Name	Function Category	Notes
unit::wait_data_ready	Control and Data Acquisition	
unit::get_data	Control and Data Acquisition	
unit::get_scalar_data	Control and Data Acquisition	
END BIAS LOOP		
instr::zero_supplies	Initialization	
unit::fill_outds	Control and Data Acquisition	

Handling Signals and Exceptions

A variety of conditions may result in termination of a measurement. Among the most common exceptions for a driver is an I/O timeout. Timeouts usually occur when one or more of the following conditions is present:

- Instruments are turned off
- Cabling is incorrect
- The driver software makes errors with respect to instrument protocol or the time required by the instrument's operations

There are numerous examples in the *hp4194* and *cvu_4194* functions code that demonstrate setting the timeout before making different queries to the instrument. A timeout is usually detected as a value of -1, returned from the *spoll, readstring,* or *writestring* functions of the *hpib_io_port* used by the driver software.

In addition to instrument I/O problems, either of the following *signals* may be generated:

- **SIGFPE** This signal occurs when the code executes an operation like a divide by zero. By default, there is no provision in IC-CAP for trapping this signal.

NOTE

If this signal occurs during *Measure,* the default handling of SIGFPE terminates the measurement; if it occurs during the execution of a transform, the function or macro will continue to execute and upon completion, an error message is displayed indicating a floating point error occurred.

- **SIGINT** This signal is generated when you issue the Interrupt command. By default, there is no provision in IC-CAP for trapping this signal. The measurement is terminated immediately. Note: For complex operations, it may take several minutes before control is returned.

If your application requires special error recovery for these signals, it is possible to trap them. For details, refer to "Handling Signals and Exceptions" in the *User's Guide*.

NOTE Do not alter the handling of SIGUSR1 and SIGUSR2; both signals are used internally by IC-CAP for error trap and recovery purposes.

3 SPICE Simulators

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This chapter describes the details of using the SPICE simulators with IC-CAP. For general information on IC-CAP simulation, refer to Chapter 6, “Simulating,” in the *User’s Guide*.

NOTE The Solaris OS must include the cpp utility, which IC-CAP uses to manage output from SPICE simulators. See “System Requirements" in the *Installation and Configuration Guide* for more details.

IC-CAP can interface with the following SPICE simulators. They are provided as a courtesy to IC-CAP users (though not supported by Agilent Technologies), and you must purchase a license to use them.

- SPICE2 The SPICE2G.6 simulator developed at U.C. Berkeley.
- SPICE3 The SPICE3E2 simulator developed at U.C. Berkeley.

- HPSPICE The Agilent Technologies implementation of SPICE2. Although there are some differences between this version and the SPICE2G.6 version from U.C. Berkeley, these 2 simulators are compatible. For more information refer to "SPICE Simulator Differences" on page 265. The version of HPSPICE provided with IC-CAP can be run only from within the IC-CAP program—it cannot be run stand-alone.

NOTE The HSPICE simulator, developed by Cadence, uses input deck syntax similar to that of the SPICE-type simulators; thus, it is referred to as a SPICE-type simulator in this manual. IC-CAP currently supports only the features of HSPICE also available in the U.C. Berkeley SPICE simulators.

The SPICE simulators support the following analysis types:

- DC
- AC
- Transient
- Noise
- Capacitance Voltage (CV)
- 2-Port (S,H,Y,Z,K,A parameter)
- Time-Domain Reflectometry (TDR)

NOTE The latter 3 simulation types are not directly available in the SPICE simulators; IC-CAP builds the additional circuitry required in the simulator input files to perform the simulation.

IC-CAP supports the features of ELDO that are also available in the UCB SPICE simulators but also provides limited support for models written in either ELDO-FAS or HDL-A. ELDO is an analog simulator developed by Mentor Graphics Corp. ELDO input deck syntax is compatible with that of the SPICE type simulators; therefore, in ELDO is categorized as a SPICE-type simulator this manual.

The IC-CAP version of SPICE3 supports the following models:

Model Group	Supported Models	Model Files
MOSFET	Level 1, Level 2, Level 3	nmos/pmos2 nmos3/pmos3
	BSIM3, BSIM4	BSIM3_DC_CV_Measure BSIM3_DC_CV_Extract BSIM3_RF_Measure BSIM3_RF_Extract BSIM3_AC_Noise_Tutorial BSIM3_CV_Tutorial BSIM3_DC_Tutorial BSIM3_Temp_Tutorial BSIM3_DC_CV_Finetune BSIM4_DC_CV_Measure BSIM4_DC_CV_Extract BSIM4_RF_Measure BSIM4_RF_Extract BSIM4_DC_CV_Tutorial BSIM4_DC_CV_Finetune
	MOS Model 9	mm9 mm9_demo
BJT	Gummel Poon	bjt_npn/bjt_pnp bjt_nhf bjt_ncehf bjt_ft mnsnpn sabernpn
GaAs	Statz	UCBGaas UGaashf
Diode	PN Diode	pn_diode
	Philips JUNCAP	juncap

The following additional SPICE-like simulators are also discussed in this chapter:

- PRECISE
- PSPICE

SPICE Simulation Example

The circuit description is predefined for all IC-CAP configuration files. Enter this description if a new model is being defined; edit the description to fit specific needs. The syntax is identical to the syntax used for describing circuits in a typical SPICE simulation deck.

This simulation example will use the IC-CAP supplied Model *bjt_npn.mdl*.

1. Select the simulator by choosing **Tools > Options > Select Simulator > spice2**. Choose **OK**.
2. Choose **File > Open > bjt_npn.mdl**. Choose **OK**.
3. View the circuit description by clicking the **Circuit** tab.

   The circuit description is shown in Figure 7. This deck describes the circuit (in this case, a single device) to be used in the simulation.
4. To view input and output for the fearly setup, click the **DUTs-Setups** tab and select **fearly**.

   The Measure/Simulate folder appears with the inputs vb, vc, ve, and vs, and the output ic. The vc input specifies a voltage source at node C that sweeps linearly from 0 to 5V in 21 steps. The ic output specifies that current at node C be monitored.

   In the Plots folder, icvsvc is specified so that the results of the simulation can be viewed graphically.
5. To simulate, click the **Simulate** button in the Measure/Simulate folder. The Status line displays Simulate in progress.

   When the simulation is complete, the Status line displays IC-CAP Ready.
6. To view the results of the simulation, display the Plots folder and click **Display Plot**. The plot displays measured data represented by solid lines and simulated data represented by dashed lines.

NOTE For syntax examples of running a remote simulation, refer to "Remote Simulation Examples" in the *User's Guide*.

```
Q1   1 = C 2 = B 3 = E 4 = S NPN AREA = 1.0
.MODEL NPN NPN
+ IS = 36.76e-18
+ BF = 336.1
+ NF = 1.003
+ VAF = 35.25
+ IKF = 22.07m
+ ISE = 1.882f
+ NE = 1.932
+ BR = 4.103
+ NR = 1.005
+ VAR = 1.651
+ IKR = 147.3u
+ ISC = 15.69f
+ NC = 1.857
+ RB = 522.0
+ IRB = 61.43u
+ RBM = 1.000m
+ RE = 8.435
+ RC = 57.05
+ XTB = 1.700
+ EG = 1.110
+ XTI = 3.000
+ CJE = 44.06f
+ VJE = 871.7m
+ MJE = 429.9m
+ TF = 10.49p
+ TR = 1.700m
+ XTF = 247.4
+ VTF = 1.622
+ ITF = 140.6m
+ PTF = 218.8
+ CJC = 68.94f
+ VJC = 603.8m
+ MJC = 290.6m
+ XCJC = 300.0m
+ TR = 1.700n
+ CJS = 111.9f
+ VJS = 465.0m
+ MJS = 241.9m
+ FC = 500.0m
```

Figure 7 Circuit Description Deck for an NPN Bipolar Transistor

Piped and Non-Piped Simulations

The following sections describe the differences in piped and non-piped simulations for the various SPICE simulators. Each section also describes the argument syntax required to invoke each of the template simulators. This information is needed when writing the user translation module, since these are the arguments supplied by IC-CAP when it calls the translation module. For information on the translation module and adding a simulator, refer to the section "Adding a Simulator" in the *User's Guide*.

Piped and Non-Piped SPICE Simulations

A non-piped simulation receives the input deck information from a file, performs the simulation and sends the binary output data and resulting text output to other files. The simulator process is restarted for every simulation.

A piped simulation receives the input deck information from a pipe connected to *standard input*, performs the simulation and sends the output data to a pipe connected to *standard output*. The simulator process will remain on until another simulator is selected. Setting the RETAIN_SIMU variable to TRUE overrides this behavior and allows multiple simulators to remain running. This uses additional memory but increases speed when frequently switching between simulators. In all cases, a piped simulator process will be turned off when the Simulation Debugger is turned on.

The text output from a simulation usually contains an explanation of any errors which may have been encountered during the simulation. Piped simulations do not save any text output from the simulation. If an error occurs during a piped simulation, IC-CAP issues a message in an error box stating that an error has occurred and recommending that the simulation be repeated with the Simulation Debugger turned on. IC-CAP performs non-piped simulations when the Simulation Debugger is ON.

In general, piped simulations are faster than non-piped simulations for any given simulator because the simulator process does not have to be restarted for every simulation and less file activity is required.

Syntax: Non-Piped 2G.6, 3E2, and HPSPICE Simulations

The command formats for non-piped simulations are shown next:

UCB SPICE 2G.6

```
ucbspice2g6 rawfile
```

where:

rawfile is the output binary data file.

The input deck file containing the circuit description and analysis commands comes from *standard input* and the output text file containing the results of the simulation goes to *standard output*.

UCB SPICE 3E2

```
spice3e2 -b -r rawfile -o textfile deckfile
```

where:

-b specifies batch mode.

rawfile is the output binary data file.

textfile is the output text file containing the results of the simulation.

deckfile is the input deck file containing the circuit description and analysis commands.

HPSPICE

```
spice2.4n1 deckfile textfile rawfile
```

where:

deckfile is the input deck file containing the circuit description and analysis commands.

textfile is the output text file containing the results of the simulation.

rawfile is the output binary data file.

Syntax: Piped 2G.6, 3E2, and HPSPICE Simulations

The command formats for piped simulations are shown next:

UCB SPICE 2G.6

```
ucbspice2g6 -
```

where:

The "-" denotes that the binary data output is going to the *standard output* pipe. The input deck information comes from the *standard input* pipe and the output text is sent to the file */dev/null*.

UCB SPICE 3E2

```
spice3e2 -s
```

where:

The *-s* option specifies that the input deck information is coming from *standard input* and the binary data output is going to *standard output*.

HPSPICE

```
spice2.4n1 - /dev/null -
```

where:

The first "-" denotes that the input deck information is coming from the *standard input* pipe.

The output text is sent to the file */dev/null*.

The last "-" denotes that the binary data output is going to the *standard output* pipe.

Non-Piped HSPICE Simulations

NOTE Prior to IC-CAP 2006B Addon3, IC-CAP did not support the CAN_PIPE token for HSPICE in usersimulators. This token may now be used on local Linux and local Solaris HSPICE simulations with Hspice-2007.03-SP1. It is not a true piped mode (netlists and raw files are still written to disk), but provides substantial performance improvement by using an interactive mode that avoids restarting HSPICE for every simulation.

Non-piped HSPICE simulations are identical to non-piped SPICE simulations. This type of simulation is performed when the Simulation Debugger is set to ON. If CANNOT_PIPE is specified for HSPICE, even when the Simulation Debugger is OFF, it still performs a non-piped simulation. This means that HSPICE must be restarted for every simulation. Because of this, there is no noticeable difference in simulation speed when the Simulation Debugger is set to ON or OFF.

Syntax: Piped HSPICE Simulations

The command format for an HSPICE non-piped simulation is as follows:

```
hspice -I
```

load deckname and *run* commands are then passed to the running HSPICE process.

Syntax: Non-Piped HSPICE Simulations

The command format for an HSPICE non-piped simulation is as follows:

```
hspice -i deckfile -o logfile
```

where

deckfile is the input deck file containing the circuit description and analysis commands.

logfile is the listing of information about the simulation generated by HSPICE. If the simulation debugger is open, this file will be displayed in the *Output Text* portion of the simulation debugger.

The output binary data file is written to a file named *deckfile.suffix* where *suffix* depends on the type of analysis being performed. Refer to the *HSPICE User's Manual* for more information.

Syntax: Client / Server mode HSPICE Simulations

On Windows, provides a method of invoking a standing server process to access HSPICE licenses. If this was launched via the *hspui* program, IC-CAP can simulate faster by launching HSPICE with the followin syntax:

```
hspice -C deckfile -o logfile
```

where

deckfile is the input deck file containing the circuit description and analysis commands.

logfile is the listing of information about the simulation generated by HSPICE. If the simulation debugger is open, this file will be displayed in the *Output Text* portion of the simulation debugger.

However, if the server has not been started, the simulation still occurs but at a slower speed.

To configure IC-CAP to send the *-C* instead of *-i*, specify the template name *hspice-C* as the second field in your usersimulators line example:

```
hspiceC hspice-C c:\synopsys\Z-2007.09\bin\hspice.exe ""
CANNOT_PIPE
```

Non-Piped ELDO Simulations

Non-piped ELDO simulations are identical to non-piped SPICE simulations. This type of simulation is performed when the Simulation Debugger is set to ON. ELDO is not capable of performing a piped simulation, so even when the Simulation Debugger is OFF, it still performs a non-piped simulation. This means that ELDO must be restarted for every simulation. Because of this, a there is no noticeable difference in simulation speed when the Simulation Debugger is set to ON or OFF.

Syntax: Non-Piped ELDO Simulations

The command format for an ELDO non-piped simulation is as follows:

```
eldo deckfile
```

where

deckfile is the input deck file containing the circuit description and analysis commands. The name of this deckfile is in the form <*circuit_name*>.*cir*.

The output binary data file is written to a file named <*circuit_name*>.*spi3*. This output binary data format is similar to the output binary format of the UCB SPICE3 simulator and is generated when you specify the option

```
.option spi3bin
```

Refer to the ELDO User's Manual for more information.

The output text file, is sent to the file named <*circuit_name*>.*chi* This file is displayed in the Output table of the Simulation Debugger if it is on.

Output Data Formats

The example in the following figure shows the output data format of the *spice2* template simulator supported in IC-CAP.

```
Record 1:  Title card (80 bytes), date (8 bytes), time (8 bytes) TOTAL-96 BYTES
Record 2:  Number of output variables (including "sweep" variable) (2 bytes)
Record 3:  Integer '4' (2 bytes)
Record 4:  Names of each output variable (8 bytes each)
Record 5:  Type of each output (2 bytes each)
          0  = no type
          1  = time
          2  = frequency
          3  = voltage
          4  = current
          5  = output noise
          6  = input noise
          7  = HD2
          8  = HD3
          9  = DIM2
         10  = SIM2
         11  = DIM3
           Outputs 7 through 11 are distortion outputs.
Record 6: The location of each variable within each sweep point. (2-bytes each)
          (Normally just 1,2,3,4,...but needed if outputs are mixed up)
Record 6a: 24 characters that are the plot sub-title if Record 3 is a '4'.
Record 7: Outputs at first sweep point
Record 8: Outputs at second sweep point
Record 9:
          .
          .
          .
last record
All real data are 8-byte quantities.
All complex data are single precision reals, that is 4-byte quantities.
    (4-byte quantity for the real part,
     4-byte quantity for the imaginary part)
EOF       A special "end-of-file" indicator: 9.87654321D+27 for real data
                                    (9.876E+0,5.432E+0) for complex data
EOI       A 4 byte integer zero indicates the end of all raw data
```

Figure 8 Output File Format Used For spice2

The binary format output by the *spice3* template simulator is shown in the following figure.

```
Title Card              (Newline (\n) terminated string)
Date and Time           (Newline (\n) terminated string)
Plot Title              (Newline (\n) terminated string)
Flags                   (Newline (\n) terminated string)
Number of Variables     (No. Variables: [an integer])
Number of Points        (No. Points: [an integer])
Version                 (Newline (\n) terminated string)
Variables List
                (Variables:
  [tab]   (index)   [tab]   (name)   [tab]   (type)
  .
                                    .
                                    .
                    {  repeated num_var times }
  where:  index = variable index  [integer]
          name = variable name    [string]
          type = variable type    [string (that is, "current" or "voltage")]
          num_var = number of variables
Binary:                      ( Newline (\n) terminated string indicating the
                               start of the binary data )
Each data point is listed in the order listed in the variables list.
Each real data point is represented by 8 bytes.
Each complex data point consists of the real part and the imaginary
part of 8 bytes each.
There are no separators between data points.
```

Figure 9 Output File Format Used For spice3

SPICE Parameter Sweeps

NOTE

Parameter sweeps should always be the outer most sweep.

LSYNC sweeps should have master sweeps that are also parameter sweeps.

For SPICE-type simulators, specifying parameter sweeps for devices and circuits requires an input added to the setup (in this example, *nmos2/short/idvd*) with Mode *P*.

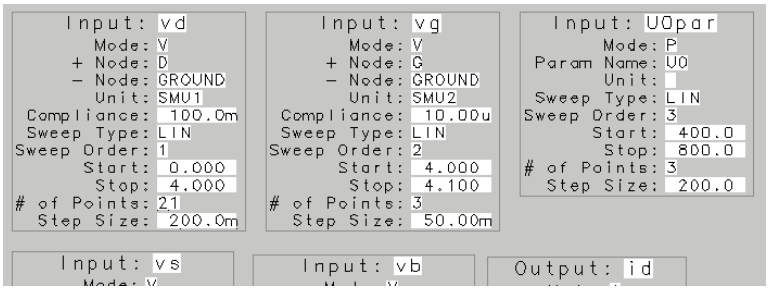

Figure 10 SPICE Parameter Sweep Setup Example

IC-CAP performs a simulation for each value of the parameter sweep. The following figure shows the resulting plot.

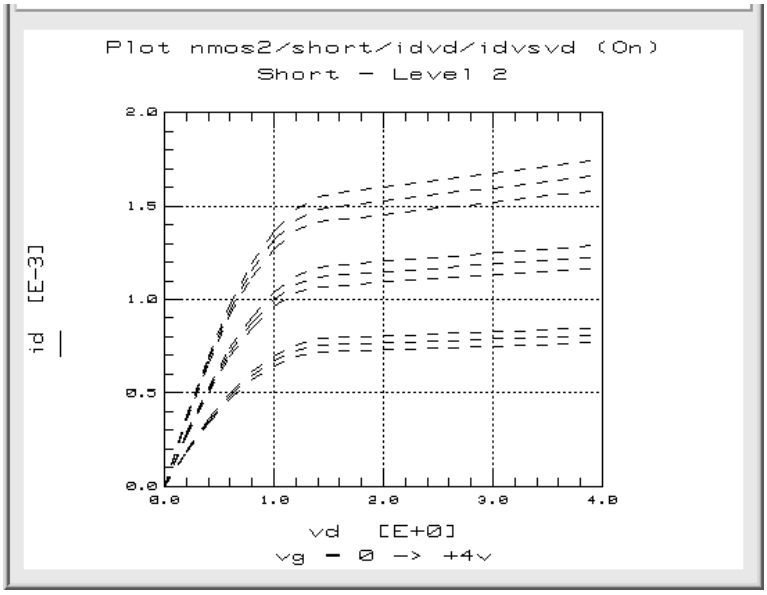

Figure 11 SPICE Parameter Sweep Plot Example

For additional information on sweeping parameters, refer to the section, "Specifying Parameter or Variable Sweeps" in the *User's Guide*.

Circuit Model Descriptions

The circuit description for the HSPICE and ELDO simulators is similar to the UCB SPICE simulator circuit description. The details in the following sections also apply to HSPICE and ELDO.

Specifying Simulator Options

For information on available options and their syntax, refer to the *User's Manual* for that simulator. Simulator options are specified in the first line of the circuit definition using the following syntax:

```
.OPTIONS OPT1 = OPTVAL1 OPT2 = OPTVAL2 ... OPTN = OPTVALN
```

where

*OPT*s denote the option keywords used by the simulator

*OPTVAL*s are the corresponding option values. Some options do not require a value; this field may or may not be specified, depending on the option.

A space is the only delimiter required between options.

The nominal and operating temperatures, TNOM and TEMP, are commonly used options; they can also be specified by entering a value (in °C) for the global variables TNOM and TEMP. To do this, enter the variable and its value in the System Variables table in the Utilities application.

- TNOM is the temperature at which the model parameters are extracted; TEMP is the temperature at which the simulation is performed. When performing an optimization to extract model parameters, TEMP and TNOM should be set to the same value so that simulations during optimization are performed at TNOM. TNOM must be defined to guarantee consistency between simulation and extraction.

- In general, TNOM and TEMP can be in any variable table, allowing different Models, DUTs or Setups to use different nominal and operating temperatures. IC-CAP checks for these global variables before running a simulation. If the variable is not found, the value of the option set in the .OPTIONS statement in the Circuit Editor is used when it exists. Otherwise, the circuit is analyzed using the simulator's default values.

IC-CAP automatically adds the option *POST=1* to the options list when the selected simulator is *hspice*. Specifying this option causes *hspice* to return the binary raw data file, which IC-CAP requires for reading back the simulated data. This option is not necessary when performing a Manual Simulation from the Simulation Debugger command menu because the data is not read back into IC-CAP.

Describing the Device Model

A device model is used to characterize a single SPICE element of any type. This description requires 2 parts:

- An element statement that calls a defined model
- A *.MODEL* definition, which is identical to a *.MODEL card* in SPICE

The general form of the element statement that calls the device model is:

```
DNAME NNUM1 = NNAME1 NNUM2 = NNAME2 ...NNUMN = NNAMEN MNAME
+ DPAR1 = DVAL1 DPAR2 = DVAL2 ...DPARN = DVALN
```

where

DNAME is the device name with the first letter being a simulator defined *key letter* denoting the type of model being specified.

NNUM denotes the node number connections.

NNAME denotes node names corresponding to the node numbers.

DPAR is a predefined DUT parameter name.

DVAL is the specified DUT parameter value. Refer to the *SPICE Reference* manual for DUT parameter names available for each model.

MNAME is the model name being referenced. This is the same *MNAME* specified in the *.MODEL* definition described below

A *.MODEL* definition specifies the parameters of a device model that describe a particular element. When a parameter is not specified, the default value in the model is used. The general form of the *.MODEL* definition is:

```
.MODEL MNAME TYPE PNAME1=PVAL1 PNAME2=PVAL2 ...PNAMEN=PVALN
```

where

MNAME is the model name. Regardless of the model name entered in the MNAME field of the .MODEL definition statement, IC-CAP substitutes the name of the Model as it is called in the Model List when the simulator input deck is built.

TYPE is a valid SPICE component type

PNAME is a parameter name for the particular model type

PVAL is the parameter value

As in SPICE, a plus sign (+) that appears as the first character of a line denotes a continuation of the previous line. This continuation character is often used for easier readability when specifying the *.MODEL* card.

NOTE

When using the SPECTRE simulator with either the OSI, SPECTRE442, or SPECTRE443 interfaces (see "SPECTRE Interfaces" on page 274), the LEVEL parameter for a MOS *.MODEL* card may not translate properly. IC-CAP outputs the value as a real number in the netlist, but SPECTRE requires an integer. To work around this issue, use the model type BSIM3 instead of MOS and omit the LEVEL parameter. Alternatively, enclose the LEVEL parameter with parentheses, for example, LEVEL = (11). By doing the later, IC-CAP does not flag it as a model parameter and leaves the expression alone when passing the netlist to SPECTRE.

Describing Subcircuits

A subcircuit model is used to describe a circuit that contains more than 1 element.

The syntax is similar to the syntax in SPICE. The subcircuit description must begin with a *.SUBCKT* and end with a *.ENDS* declaration. Statements between these 2 declarations describe the subcircuit components.

The general form of the first line of a subcircuit definition is:

```
.SUBCKT SUBNAME NNUM1 = NNAME1 NNUM2 = NNAME2 ...NNUMN =
NNAMEN + (PAR1=PARVAL1 PAR2=PARVAL2 ...PARN=PARVALN)
```

where

SUBNAME is the name you give to the subcircuit. Regardless of the subcircuit name entered in the SUBNAME field of the .SUBCKT definition statement, IC-CAP substitutes the name of the Model being simulated when the simulator input deck is built.

NNUM are the numbers of the external nodes of the subcircuit. These external nodes are used to connect the subcircuit to another circuit. External nodes in the *.SUBCKT* declaration cannot be 0 (ground), but internal nodes can be connected to ground and any external node to ground in a surrounding circuit.

NNAME is a node name assigned to a node number. As in the device model description, IC-CAP allows the option of equating node numbers to node names. If you assign node names, use these names when specifying the Inputs and Outputs in the Setup.

PAR1 ... PARN are subcircuit parameters that can be passed through subcircuit calls. These parameters are added to the DUT parameter table in IC-CAP.

PARVAL1 ... PARVALN are the corresponding parameter values. These subcircuit parameters become DUT parameters and can be modified in the DUT Parameter Editor.

(While the syntax shown here is correct, passed parameters are ignored by IC-CAP.)

The body of the subcircuit model description contains the components of the subcircuit using element and *.MODEL* statements.

Assigning Node Names

IC-CAP allows the option of equating node numbers to node names in circuit descriptions because it is typically easier to refer to a node by a meaningful name rather than a number. If node numbers only are specified, these node numbers must be used when specifying inputs and outputs. Node identities can also be specified with the format *%<name>*. For example:

```
Q1 1=C 2=B 3=E 4=S NPN or Q1 %C %B %E %S NPN
```

Although HSPICE and ELDO allow alphanumeric characters for node names, node numbers must still be associated with node names because IC-CAP parses HSPICE as a SPICE-type simulator.

When using this format, all node names within the circuit or device must be referenced using the *%[nodename]* syntax.

Test Circuits and Hierarchical Simulation

When characterizing a circuit, it is often necessary to add circuitry around a circuit or device to model the actual measurement Setup. IC-CAP provides a Test Circuit Editor to allow modeling of this additional bias circuitry. Select the DUT from the DUT/Setup panel. Click the Test Circuit tab and enter the test circuit description in the same manner you would enter a Circuit Description. The test circuit definition should include a call to the device or subcircuit defined in the Circuit Editor, as well as the additional circuitry needed to model the external parasitics of the measurement Setup.

NOTE When you define a test circuit, the DUT parameter table contains the values specified in the test circuit specification. Regardless of the subcircuit name entered in the SUBNAME field of the *.SUBCKT* declaration, IC-CAP uses the name of the DUT being simulated when the simulator input deck is built.

Subcircuit and device model specifications can be called from inside another Model. This enables you to perform *hierarchical simulations* to study a circuit at different levels.

When making reference to another model, the model name must be used as it appears in the IC-CAP Model List. For example, assume you have defined 3 Models, *model1, model2,* and *model3. model1* has a circuit model description that is a device definition. The circuit model description for *model2* is a subcircuit definition at the gate level that includes a call to *model1* in a device call statement. And, the circuit model description for *model3* is a subcircuit definition that includes a call to *model2* in a subcircuit call statement. When you simulate a Setup in *model3,* IC-CAP traverses the Model hierarchy and uses the circuit model description defined in *model3,* which includes calls to *model1* and *model2.* The syntax for calling a device model is identical to that described in the *Device Model Description* section.

The general form of the device call is:

```
DNAME NNUM1 = NNAME1 NNUM2 = NNAME2 ...NNUMN = NNAMEN MNAME
+ DPAR1 = DVAL1 DPAR2 = DVAL2 ...DPARN = DVALN
```

Calling a subcircuit specification allows you to insert an entire subcircuit into a circuit as if it were a single component. The call requires a syntax identical to that used in SPICE. The general form of the subcircuit call is:

```
XNAME NNUM1 NNUM2 ...NNUMN SUBNAME (PARVAL1 PARVAL2 ... PARVALN)
```

where

XNAME is the name of the subcircuit call statement. The only requirement for this name is that it must start with the letter *X.*

NNUM are the node numbers of the calling circuit that connect to the external nodes of the subcircuit. The calling circuit node numbers need not be the same as the external nodes of the subcircuit. The nodes are connected in the *order* specified. Specify the same number of nodes declared in the subcircuit definition.

SUBNAME is the name of the subcircuit, previously described by a .SUBCKT *definition*. This must have the name of the model as it appears in the Model List if it is in a different model.

PARVAL are subcircuit parameter values. The order in which they are listed in the subcircuit call statement must match the parameters list in the subcircuit definition.

(While the syntax shown here is correct, passed parameters are ignored by IC-CAP.)

NOTE

When a test circuit is included in the Model, IC-CAP uses the test circuit description as the *top level* circuit definition. The node number connections defined in the test circuit description, not the circuit description, are used as the external nodes. Because of this, any node-number-to-node-name cross-referencing in the circuit description is not used. Only node names equated to node numbers in the test circuit description can be used when specifying Inputs and Outputs in the Setup Editor. When only node numbers are specified in the test circuit description, (that is, they are not equated to node names) these same node numbers must be used in the Input and Output node fields.

Circuit Description Syntax

This section describes basic syntax rules for creating a circuit description.

SPICE Simulators

Start an input line with * to denote a comment in the circuit model description or in the input file of the simulation debugger. Although some simulators accept # and * , IC-CAP accepts * only. (# is recognized as a preprocessor directive when the simulator input deck is built. Adding a comment using # causes a simulation generated from a DUT or Setup to fail.)

Table 64 lists the SPICE element component specifications. For information on available options and their syntax, refer to the *SPICE Reference* manual.

Table 65 lists the semiconductor device specifications. For information on available options and their syntax, refer to the *SPICE Reference* manual.

Table 64 SPICE Element Component Specifications

Component	General Form	Example
Resistor	RXXXXXXX N1 N2 VALUE <TC=TC1<TC2>>	R1 1 2 1000 TC=0.001,0.015
Capacitor	CXXXXXXX N+ N- VALUE <IC=INCOND>	COSC 15 2 10U IC=3
Inductor	LXXXXXXX N+ N- VALUE <IC=INCOND>	LSHUNT 3 29 10U IC=15.7m
Mutual Inductor	KXXXXXXX LYYYYYYY LZZZZZZZ VALUE	K43 LAA LBB 0.999
Transmission Line	TXXXXXXX N1 N2 N3 N4 Z0=VALUE <TD=VALUE>+ <F=FREQ <NL=NRMLEN>> <IC=V1,I1,V2,I2>	T1 1 0 2 0 Z0=50 TD=10NS

Table 64 SPICE Element Component Specifications (continued)

Component	General Form	Example
Linear Voltage-Controlled Current Source	GXXXXXXX N+ N- NC+ NC- VALUE	G1 2 0 5 0 0.1M
Linear Voltage-Controlled Voltage Source	EXXXXXXX N+ N- NC+ NC- VALUE	E1 2 3 14 1 2.0
Linear Current-Controlled Current Source	FXXXXXXX N+ N- VNAM VALUE	F1 13 5 VSENS 5
Linear Current-Controlled Voltage Source	HXXXXXXX N+ N- VNAM VALUE	HX 5 17 VZ 0.5K
Independent Voltage Source	VXXXXXXX N+ N- <<DC> DC/TRAN VALUE> + <AC <ACMAG <ACPHASE>>>	VIN 12 0 DC 6
Independent Current Source	IXXXXXXX N+ N- <<DC> DC/TRAN VALUE> + <AC <ACMAG <ACPHASE>>> + SFFM(0 1 10K 5 1K)	ISRC 23 21 AC 0.333 45.0

Table 65 SPICE Semiconductor Component Specifications

Component	General Form	Example
Junction Diode	DXXXXXXX N1 N2 MNAME + <AREA><OFF><IC=VD>	DCLAMP 3 7 DMOD 3.0 IC=0.2
BJT	QXXXXXXX NC NB NE <NS> MNAME + <AREA> <OFF> <IC=VBE,VCE>	Q2A 11 26 4 20 MOD1
JFET	JXXXXXXX ND NG NS MNAME + <AREA> <OFF> <IC=VDS,VGS>	J1 7 2 3 JM1 OFF

Table 65 SPICE Semiconductor Component Specifications (continued)

Component	General Form	Example
MOSFET	MXXXXXXX ND NG NS NB MNAME + <L=VAL><W=VAL><AD=VAL><AS=VAL> +<PD=VAL><PS=VAL><NRD=VAL><NRS=VAL> + <OFF> <IC=VDS,VGS,VBS	M1 2 9 3 0 MOD1 L=10U W=5U

HSPICE Simulator

Basic HSPICE syntax rules are the same as SPICE-type simulators. Refer to the *HSPICE User's Manual* for complete syntax and rules.

NOTE Before performing HSPICE simulations, specify the HSPICE version name in the System Variable HSPICE_VERSION. If this variable is not specified, IC-CAP will assume the latest version of HSPICE is being used.

ELDO Simulator

Basic ELDO syntax rules are the same as SPICE-type simulators. In addition to the SPICE-type syntax, FAS user-defined models can be defined and instantiated in the IC-CAP Circuit Editor. An FAS model is defined as:

```
amodel name(pin1,pin2..)
.
<model body>
.
endmodel
```

(smodel and fmodel are also accepted).

The above model is instantiated in a circuit as:

```
yxx name [pin:] 1 2 ... [param: par1 = var1 ...] [model: ...]
```

In addition, the parser accepts the following ELDO constructs:

```
.ADDLIB number pathname
#com . . #endcom
```

FIDEL models (**o**xx p1:typ p2:typ ... mod=modelname) and transfer functions (FNS, FNZ) are not currently supported by the IC-CAP parser. However, the *#echo* keyword can be used to insert these statements into a circuit in the IC-CAP Circuit Editor.

The *#echo* keyword is available in the IC-CAP Circuit Editor for all supported simulators. *#echo* can be used to pass a deck card or command directly through to the simulator without any parsing by IC-CAP. For example, the line

```
#echo <something that the IC-CAP parser doesn't understand>
```

is sent to the simulator as

```
<something that the IC-CAP parser doesn't understand>
```

The following analog model instantiation syntax is supported for HDL-A:

HDL-A user-defined models with the following syntax can also be instantiated in the IC-CAP Circuit Editor.

```
yxx name(xx) [pin:] 1 2 ... [param: par1 = var1 ...]
```

and

```
yxx name(xx) [pin:] 1 2 ... [generic: par1 = var1 ...]
```

NOTE Before performing ELDO simulations specify the ELDO version name in the System Variable ELDO_VERSION. If this variable is not specified, IC-CAP will use the version name specified in the environment variable *eldover*, if it exists. If neither ELDO_VERSION or *eldover* are specified, IC-CAP assumes that the latest version of ELDO is being used.

SPICE Simulator Differences

Subtle differences in syntax, behavior, error handling and calculation of data between the simulators must be considered when creating a circuit description.

- SPICE2 simulations will fail if an underscore is used in the Model name. An error message will appear in the output text file generated by the Simulation Debugger:

  ```
  0*ERROR*: MODEL TYPE IS MISSING
  ```

- SPICE2 simulations will fail if an underscore is used in a test circuit and DUT name because the simulation input deck uses the DUT name as a model name. An error message will appear in the output text file:

  ```
  0*ERROR*: SUBCIRCUIT NODES MISSING
  ```

- When attempting a SPICE2 or SPICE3 simulation in the BJT model, if the ideal maximum forward beta parameter BF=0 or the transport saturation current parameter IS=0, the simulation will fail without an error message. (Other parameters may yield similar results when set to zero.)
- SPICE3 is the only simulator that supports the UCB GaAs model. Refer to "Simulators" in the *Nonlinear Device Models, Volume 1* manual for details on the syntax required to simulate this model.
- HPSPICE is the only simulator that supports the Curtice GaAs model. Refer to "Simulators" in the *Nonlinear Device Models, Volume 1* manual for details on the syntax required to simulate this model.
- When using HPSPICE to simulate a UC Berkeley MOSFET model, specify the *ucb* option in the *.OPTIONS* statement of the circuit description:

  ```
  .OPTIONS ucb
  ```

- When using SPICE3 with the Simulation Debugger to perform an IC-CAP simulation (as opposed to a manual simulation), an output text file with the following message results: *print card ignored since rawfile was produced*. To generate a more informative output text file, perform a manual simulation. The manual simulation results in an output text file that includes the requested output data values.

Using the PRECISE Simulator with IC-CAP

PRECISE is a UCB SPICE-based simulator developed by Mentor Graphics Corp. Using IC-CAP's Open Simulator Interface, a C-language *Translation Module* is provided that makes PRECISE simulation capability available in IC-CAP. This module and instructions for performing PRECISE simulations in IC-CAP are described here. For general information on the Open Simulator Interface, refer to the section "Adding a Simulator" in the *User's Guide*.

The IC-CAP/PRECISE link uses UCB SPICE2G.6 as the *template* simulator. When performing a PRECISE simulation in IC-CAP, IC-CAP behaves as if it is performing a SPICE2 simulation. Therefore it generates an input deck in SPICE2 format, calls the simulator and reads back a binary raw data file in SPICE2 format. Through the Open Simulator Interface, the call to the simulator is actually calling the executable version of the C-language *Translation Module, precise.c*. This executable, called *precise,* translates the SPICE2 input deck to a PRECISE input format, calls PRECISE to perform the simulation, then translates the PRECISE format binary raw data file to SPICE2 format which is read by IC-CAP. The source code file *precise.c* is located in the *$ICCAP_ROOT/src* directory.

To set up PRECISE simulation capability in IC-CAP:

1. Add the *precise* simulator to the *usersimulators* file in the directory *$ICCAP_ROOT/iccap/lib*, as shown next:

   ```
   precise spice2 /<your path>/precise "<host_machine_name>"
   CANNOT_PIPE
   ```

2. The *host_machine_name* is the host computer for the PRECISE simulations. This name can be left blank ("") if PRECISE and IC-CAP are running on the same computer. Since PRECISE does not have the ability to perform piped simulations in IC-CAP, the CANNOT_PIPE flag must always be set, as shown in the above example.

NOTE The IC-CAP/PRECISE interface is only supported for the HP 9000 Series 700 version of PRECISE. Therefore the host computer must be a Series 700 workstation.

3 Make the following changes to the *precise.c* program to customize it for your environment:
   - In the *main* routine, specify the full pathname of the actual PRECISE simulator on your system.
   - In the *spice2_to_precise* routine, specify the full pathname of the Mentor Graphics supplied program *ppphp700.exe,* which translates a SPICE2 input deck to the equivalent PRECISE input deck.

4 Compile the translation module using the following command:
```
cc -o precise precise.c -lm
```

5 Move the executable file, *precise* to a permanent location such as *$ICCAP_ROOT/bin* The location must match the path specified in the *usersimulators* file.

6 In IC-CAP, set the SIMULATOR variable to *precise* or specify *precise* with the *Select Simulator* command on the IC-CAP Tools Menu.

The following files are generated in your home directory when running PRECISE simulations in IC-CAP:

- *namefile* - File that contains the name of the spice input deck file *indeck.spi.*
- *indeck.spi* - SPICE 2G.6 format input deck file that is the input to the input deck translator program *ppphp700.exe* provided by Mentor Graphics.
- *indeck.ckt* - PRECISE format circuit description deck output from the input deck translator program *ppphp700.exe.*
- *indeck.use* - PRECISE format analysis command deck output from the input deck translator program *ppphp700.exe.*
- *xndeck.use* - PRECISE format analysis command deck referenced by *indeck.use.* Also generated by the input deck translation.

- *rawout* - PRECISE formatted binary raw data output file generated by a PRECISE simulation.

Using the PSPICE Simulator with IC-CAP

PSPICE is a SPICE-based circuit simulator developed by MicroSim Corporation. PSPICE uses the same basic numeric algorithms as the UCB SPICE2 simulator but claims superior convergence and performance. Using IC-CAP's Open Simulator Interface, a C-language *Translation Module* is provided that makes PSPICE simulation capability available in IC-CAP. This module and instructions for performing PSPICE simulations in IC-CAP are described here. For general information on the Open Simulator Interface, refer to the section "Adding a Simulator" in the *User's Guide*.

The IC-CAP/PSPICE link uses UCB SPICE2 as the *template* simulator. When performing a PSPICE simulation in IC-CAP, IC-CAP behaves as if it is performing a SPICE2 simulation. Therefore it generates an input deck in SPICE2 format, calls the simulator and reads back a binary raw data file in SPICE2 format. Through the Open Simulator Interface, the call to the simulator is actually calling the executable version of the C-language *Translation Module, pspice.c*. This executable, called *pspice,* translates the SPICE2 input deck to a PSPICE input format, calls PSPICE to perform the simulation, then translates the PSPICE format binary raw data file to SPICE2 format which is read by IC-CAP. The source code file *pspice.c* is located in the *$ICCAP_ROOT/src* directory.

NOTE The IC-CAP/PSPICE translation module *pspice.c* has been updated in IC-CAP 5.0 to support the output binary data format of PSPICE 6.3. Only PSPICE versions with the identical output binary data format will work with this translation module. For older PSPICE versions, use the translation module *pspice5_4.c*, also supplied with this release.

To set up PSPICE simulation capability in IC-CAP:

1 Add the *pspice* simulator to the *usersimulators* file in the directory *$ICCAP_ROOT/iccap/lib*, as shown next.

```
pspice spice2 /<your path>/pspice "<host_machine_name>"
CANNOT_PIPE
```

2 The *host_machine_name* is the host computer for the PSPICE simulations. This name can be left blank ("") if PSPICE and IC-CAP are running on the same computer. Since PSPICE does not have the ability to perform piped simulations in IC-CAP, the CANNOT_PIPE flag must always be set, as shown in the above example.

3 Make the following change to the *pspice.c* program to customize it for your environment:

- In the *main* routine, specify the full pathname of the actual PSPICE simulator on your system.

4 Compile the translation module using the following command:

```
cc -o pspice pspice.c -lm
```

5 Move the executable file, *pspice* to a permanent location such as *ICCAP_ROOT/bin*. The location must match the path specified in the *usersimulators* file.

6 In IC-CAP, set the SIMULATOR variable to *pspice* or specify *pspice* with the *Select Simulator* command in the IC-CAP Tools Menu.

The following files are generated in your home directory when running PSPICE simulations in IC-CAP:

- *psp.cir* - PSPICE format circuit description deck file translated from the SPICE2 circuit description deck.
- *psp.raw* - PSPICE formatted binary raw data output file generated by a PSPICE simulation.
- *psp.out* - Output print file generated by a PSPICE simulation.

psp.raw and *psp.out* are automatically removed from your home directory after the simulation is completed in IC-CAP.

NOTE When using PSPICE, the LM_LICENSE_FILE environment variable must be set. This variable contains the directory path for the license file required by the PSPICE simulator. Refer to the PSPICE Reference Manual for detailed procedures on installing the PSPICE simulator.

4
SPECTRE Simulator

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This chapter describes the details of using the SPECTRE simulator with IC-CAP. For general information on IC-CAP simulation, refer to Chapter 6, “Simulating,” in the *User’s Guide*.

SPECTRE Interfaces

SPECTRE is a SPICE-like circuit simulator developed by Cadence Design Systems that simulates analog and digital circuits at the differential equation level using direct methods.

SPECTRE uses the same basic algorithms used in UCB SPICE but the implementation of these algorithms uses the most up-to-date methods currently available.

IC-CAP offers 3 different interfaces for use with the SPECTRE simulator:

- SPECTRE
- SPECTRE443
- SPECTRE442

SPECTRE Interface

The SPECTRE interface is compatible with SPECTRE version 4.4.3 simulators and later. Unlike the SPECTRE443 and SPECTRE442 interfaces which invoke the SPICE netlist parser, this interface uses native SPECTRE netlist syntax to parse data from the circuit page. This alleviates the need to translate SPECTRE netlists to SPICE syntax prior to entering the netlists on the circuit page. See the following section, "Valid SPECTRE Netlist Syntax for IC-CAP" on page 277."

SPECTRE443 Interface

This interface is compatible with SPECTRE versions up to 5.0.0. The SPECTRE443 interface invokes a SPICE netlist parser, unlike the SPECTRE implementation which uses native SPECTRE netlist syntax to parse data from the circuit page. This interface requires that SPECTRE netlists are first converted to SPICE syntax prior to entering them on the circuit page.

SPECTRE442 Interface

This interface is compatible with SPECTRE simulator version 4.2.2 only. The SPECTRE442 interface invokes the SPICE netlist parser, unlike the SPECTRE interface which uses native SPECTRE netlist syntax to parse data from the circuit page. This interface requires that SPECTRE netlists are first converted to SPICE syntax prior to entering them on the circuit page.

CAUTION The SPECTRE442 interface is no longer recommended. IC-CAP is only tested against the latest version of SPECTRE. The SPECTRE442 interface is documented only to assist in migrating to the SPECTRE443 or SPECTRE interface.

Open Simulator Interface (OSI)

This interface requires the compilation of a translation module (see spectre3.c in $ICCAP_ROOT/src). This translation module allows IC-CAP to operate as though it is interfacing to SPICE 3. This interface is no longer recommended, but is documented to help migration efforts from the old interface to the new SPECTRE interface template. For details, see “Using Template SPICE3 and the Open Simulator Interface spectre3.c” on page 288.

Circuit Model Descriptions

The following section describes the type of circuit page netlists required when using the SPECTRE interface. Please refer to "Circuit Model Descriptions" on page 254 for the netlist requirements for the SPECTRE443, SPECTRE442, or the SPICE3 OSI interfaces.

For valid circuit syntax descriptions, see the Cadence SPECTRE simulator user's documentation.

Specifying Simulator Options

For information on available simulator options and their syntax, refer to the Cadence SPECTRE simulator user's documentation.

Simulator options are specified in the first line of the circuit definition using the following syntax:

```
options OPT1 = OPTVAL1 OPT2 = OPTVAL2 ... OPTN = OPTVALN
```

where

OPT denotes the option keyword used by the simulator.

OPTVAL is the corresponding option value. Some options do not require a value. This field may or may not be specified, depending on the option.

A space is the only delimiter required between options.

The nominal and operating temperatures, TNOM and TEMP, are commonly used options. TNOM is the temperature at which the model parameters are extracted. TEMP is the temperature at which the simulation is performed.

NOTE When performing an optimization to extract model parameters, TEMP and TNOM should be set to the same value so that simulations during optimization are performed at TNOM. TNOM must be defined to guarantee consistency between simulation and extraction.

You can also specify these variables by entering a value (in °C) for the global variables TNOM and TEMP in the System Variables table in the Utilities application.

In general, TNOM and TEMP can be in any variable table, allowing different Models, DUTs or Setups to use different nominal and operating temperatures.

IC-CAP checks for these global variables before running a simulation. If it does not find the variable, IC-CAP uses the value set in the Circuit Editor options statement. Otherwise, IC-CAP analyzes the circuit using the simulator's default values.

Valid SPECTRE Netlist Syntax for IC-CAP

The SPECTRE interface parses netlists written in native SPECTRE syntax.

During a simulation using the SPECTRE template, IC-CAP examines the netlist entered on the Circuit page for:

- The name of the device to be modelled
- The external nodes of the device
- The model-level parameters
- The device-level parameters

IC-CAP is intended for single-device model extractions. Therefore, not all valid SPECTRE netlists are accepted by IC-CAP.

Valid SPECTRE Constructs

IC-CAP uses 3 SPECTRE constructs:

- the device statement
- the subcircuit (subckt) block
- the model statement

Valid SPECTRE Circuit Page Configurations

There are 3 valid Circuit page configurations:

- A single device statement *and* a single model card
- A single subcircuit block
- A single device statement followed by a single subcircuit block

NOTE Other supporting statements can be added in and around the configurations mentioned above. This includes all valid SPECTRE syntax statements *other than* the device, subckt, and model statements. These 3 constructs are limited in number and combination as described above.

Describing a Device

A device statement describes a single SPECTRE element of any type. The general form of device statement is:

```
DNAME NODE1 NODE2...NODEN MNAME DPAR1=DVAL1 DPAR2=DVAL2
```

where

DNAME is the device name with the first letter being a simulator-defined *key letter*, denoting the type of model being specified.

NODE denotes the node name for the device connection.

MNAME is the name of a built-in device, or the name of a model or subcircuit definition. This is the same *MNAME* specified in the *model* definition described below.

DPAR is a predefined DUT parameter name.

DVAL is the specified DUT parameter value. Refer to the *MNS and SPICE Reference* for the DUT parameter names available for each model.

A plus sign (+) that appears as the first character of a line or a back slash (\ ) that appears as the last character in a previous line denotes a continuation of the previous line. This continuation character is often used for easier readability when specifying the *model* card.

Describing the Model

A *model* definition specifies the parameters of a particular model that is referenced by a device statement (see "Describing a Device" on page 278). When a parameter is not specified, the default value in the model is used. The general form of the *model* definition is:

```
model MNAME TYPE PNAME1=PVAL1 PNAME2=PVAL2 ...PNAMEN=PVALN
```

where

MNAME is the model name. Regardless of the model name entered in the MNAME field of the *model* definition statement, IC-CAP substitutes the name of the Model as it is called in the Model List when the simulator input deck is built.

NOTE

Noise is a reserved word in SPECTRE and must not be used in naming components of the netlist. Do not use the name "*noise*" for DUTs or Models. IC-CAP substitutes the Model/DUT name for the name in the Circuit or Test Circuit folders respectively.

TYPE is a valid SPECTRE component type.

PNAME is a parameter name for the particular model type.

PVAL is the parameter value.

A plus sign (+) that appears as the first character of a line or a back slash (\ ) that appears as the last character in a previous line denotes a continuation of the previous line. This continuation character is often used for easier readability when specifying the *model* card.

Describing Subcircuits

A subcircuit model is used to describe a circuit that contains more than 1 element.

The syntax is similar to the syntax in SPICE. The subcircuit description must begin with a *subckt* and end with an *ends* declaration. Statements between these 2 declarations describe the subcircuit components.

The general form of a subcircuit definition is:

```
subckt SUBNAME (NODE1 NODE2...NODEN)
    parameters PAR1=PARVAL1 PAR2=PARVAL2 ...PARN=PARVALN

    <subcircuit devices and/or models listed here>

    ends SUBNAME
```

where

SUBNAME is the subcircuit name. Regardless of the subcircuit name entered in the SUBNAME field of the *subckt* definition statement, IC-CAP substitutes the name of the Model being simulated when the simulator input deck is built.

NOTE

Noise is a reserved word in SPECTRE and must not be used in naming components of the netlist. Do not use the name "*noise*" for DUTs or Models. IC-CAP substitutes the Model/DUT name for the name in the Circuit or Test Circuit folders respectively.

NODE denotes the node name for the device connection.

PAR1 ... *PARN* are subcircuit parameters that can be passed through subcircuit calls. If a subcircuit is used in conjunction with a device statement, then the parameters specified on the device line will also need to be listed here. In this case, those parameters are added to the DUT Parameters table. All other parameters not listed in the device statement will be added to the Model Parameters table. If the subcircuit description is used without an associated device statement, then all parameters listed here will be entered in the DUT Parameters table.

PARVAL1 ... PARVALN are the corresponding parameter values. Depending on the context (see previous paragraph), these parameters become either DUT parameters or model parameters which can be modified in the DUT Parameters table of the Model Parameters table.

The body of the subcircuit model description contains the components of the subcircuit using element and *model* statements.

Using a Device Statement and Model Card Configuration

The device statement and model card is the simplest circuit page configuration. The template parses the model card into the Model Parameters page and the device parameters into the DUT Parameters page. The device statement provides the external nodes.

Example syntax:

```
q1 C B E S NPN area = 1.0
model NPN bjt
+ is = 1E-16
+ bf = 100
```

In this case, *is* and *bf* will appear on the Model Parameters page, and *area* will appear in the DUT Parameters page.

NOTE

The device statement and model card may appear in any order.

Using a Single Subcircuit Block Configuration

This circuit page configuration interprets the subcircuit as a single device. If the subcircuit includes a Parameters statement, the template parses these parameters as device parameters, where they appear in the DUT Parameter Table. All parameters on model or device statements within the subcircuit appear in the Model Parameter Table in the form:

```
<inst/model>.<parameter>
```

Example syntax:

```
subckt realnpn (C B E)
parameters area=1
LE E 4 inductor l=.35n
LB B 5 inductor l=.2n
CC C 0 capacitor c=.255p
Q1 C 5 4 NPN area = area
model NPN bjt
+ is = 1E-16
+ bf = 100
ends realnpn
```

In this case, *LE.l*, *LB.l*, *CC.c*, *NPN.is*, and *NPN.bf* will appear in the Model Parameters table and *area* will appear in each DUT Parameters table.

NOTE

Note, *Q1.area* does not appear because its value is not a simple number. IC-CAP only identifies parameters with simple numbers for extraction.

When this circuit is simulated, IC-CAP outputs the subcircuit as well as an device statement to call the subcircuit.

See the example file *model_files/bjt/spectre_ncehf.mdl* for a working model.

Using a Device Statement Followed by a Subcircuit Block

In some situations, you must extract parameters from a device defined by a subcircuit whose parameters listed in the Parameters statement within the subcircuit are your *model* parameters and not your *device* parameters. Use the “device statement followed by a subcircuit block” configuration.

In this configuration, all parameters listed with the subcircuit *parameters* statement are parsed as *model* parameters, unless they are referenced on the device statement, in which case they are treated as *device* parameters.

Example syntax:

```
q1 C B E S realnpn area=1.0
subckt realnpn C B E S
parameters area=1.0 is=1e-16 bf=100 lb=1
lb1 B 1 inductor l=lb
q1 C 1 E S NPN area=area
model NPN bjt is=is bf=bf
ends realnpn
```

In the this example, there are 3 model parameters, *is*, *bf* and *lb*, and 1 device parameter, area.

Note the difference between this configuration and the single-subcircuit configuration which has only a *subckt* definition and no device.

Test Circuits and Hierarchical Simulation

When characterizing a circuit, it is often necessary to add circuitry around a circuit or device to model the actual measurement Setup. IC-CAP provides a Test Circuit Editor to allow modeling of this additional bias circuitry. Select the DUT from the DUT/Setup panel. Click the Test Circuit tab and enter the test circuit description in the same manner you would enter a Circuit Description. The test circuit definition should include a call to the device or subcircuit defined in the Circuit Editor, as well as the additional circuitry needed to model the external parasitics of the measurement Setup.

NOTE When you define a test circuit, the DUT Parameter table contains the values specified in the test circuit specification. Regardless of the subcircuit name entered in the SUBNAME field of the *subckt* declaration, IC-CAP uses the name of the DUT being simulated when the simulator input deck is built.

NOTE *Noise* is a reserved word in SPECTRE and must not be used in naming components of the netlist. Do not use the name "*noise*" for DUTs or Models. IC-CAP substitutes the Model/DUT name for the name in the Circuit or Test Circuit folders respectively.

Subcircuit and device model specifications can be called from inside another model. This enables you to perform *hierarchical simulations* to study a circuit at different levels.

When making reference to another model, the model name must be used as it appears in the IC-CAP Model List. For example, assume you have defined 3 models, *model1, model2,* and *model3. model1* has a circuit model description that is a device definition. The circuit model description for *model2* is a subcircuit definition at the gate level that includes a call to *model1* in a device call statement. And, the circuit model description for *model3* is a subcircuit definition that includes a call to *model2* in a subcircuit call statement. When you simulate a Setup in *model3,* IC-CAP traverses the Model hierarchy and uses the circuit model description defined in *model3,* which includes calls to *model1* and *model2.* The syntax for calling a device model is identical to that described in the *Device Model Description* section.

The general form of the device call is:

```
DNAME NODE1 NODE2...NODEN MNAME DPAR1=DVAL1 DPAR2=DVAL2
```

Calling a subcircuit specification allows you to insert an entire subcircuit into a circuit as if it were a single component. The call requires a syntax identical to that used in SPECTRE. The general form of the subcircuit call is:

```
DNAME NODE1 NODE2...NODEN SUBNAME DPAR1=DVAL1 DPAR2=DVAL2
```

where

DNAME is the name of the subcircuit call statement. The only requirement for this name is that it must start with the letter *D.*

NODE denotes the node name for the device connection.

SUBNAME is the name of the subcircuit, previously described by a *subckt* definition. This must have the name of the model as it appears in the Model List if it is in a different model.

DPAR are passed in the parameter names.

DVAL are subcircuit parameter values. The order in which they are listed in the subcircuit call statement must match the parameters list in the subcircuit definition.

NOTE

When a test circuit is included in the Model, IC-CAP uses the test circuit description as the *top level* circuit definition. The node number connections defined in the test circuit description, not the circuit description, are used as the external nodes. Because of this, any node-number-to-node-name cross-referencing in the circuit description is not used. Only node names equated to node numbers in the test circuit description can be used when specifying Inputs and Outputs in the Setup Editor. When only node numbers are specified in the test circuit description, (that is, they are not equated to node names) these same node numbers must be used in the Input and Output node fields.

Piped and Non-Piped SPECTRE Simulations

The following sections describe the differences in piped and non-piped simulations for the various SPECTRE simulators. Each section also describes the argument syntax required to invoke each of the template simulators. This information is needed when writing the user translation module, since these are the arguments supplied by IC-CAP when it calls the translation module. For information on the translation module and adding a simulator, refer to the section "Adding a Simulator" in the *User's Guide*.

There are 3 methods you can use to link to the SPECTRE simulator interface:

- Use template SPECTRE, SPECTRE443, or SPECTRE442 with CANNOT_PIPE.
- Use template SPECTRE, SPECTRE443, or SPECTRE442 with CAN_PIPE.
- Use template SPICE3 and the Open Simulator Interface *spectre3.c*.

NOTE The methods using SPECTRE or SPECTRE442/443 offer significant speed enhancements with some minor features that will not work properly. Be sure to read the following sections describing their limitations.

NOTE The method using SPICE3 is fully supported, but offers the slowest speed. It is not recommended, except when methods using SPECTRE or SPECTRE442/443 do not work, or are unavailable.

Using SPECTRE Simulator Templates with CANNOT_PIPE

If you specify the template SPECTRE, SPECTRE442 or SPECTRE443, you can greatly speed up your simulations. This template will use the SPECTRE *alter* command to simulate multiple bias steps in 1 simulation. This improves

many multi-sweep simulations such as an S-parameter setup with 2 sweeps. Using the Open Simulator Interface method, each of these bias steps would require a separate simulation.

The one known limitation with this method is that parameter sweeps will not work properly with certain parameters that are declared in a subcircuit at the Circuit page level when a Test circuit is being used. Parameters that are declared with an "=" sign will work even under this configuration, but parameters that are declared without an "=" sign will not work. In the following example, parameter sweeps will work for IS, but not for R1.

Circuit Page:

```
subckt CIRC 1=A 2=C
R1 1 2 50
Q1 1 2 1 2 NPN
model NPN BJT IS=10e-15
.ENDS
```

Test Circuit:

```
subckt CIRC2 1=A 2=C
XTEST 1 2 CIRC
.ENDS
```

Using SPECTRE Simulator Templates with CAN_PIPE

IC-CAP may not work properly with parameters defined using *$mpar()* in *#echo* lines. If using such a circuit, Agilent Technologies does not recommend using CAN_PIPE. Use CANNOT_PIPE instead.

Specifying CAN_PIPE with SPECTRE, SPECTRE442 or SPECTRE443 templates will use a mode that will allow the simulator to stay up for multiple simulations of the same setup as long as the only thing changing are parameters. This is what happens during an optimization which has all targets within 1 setup. This mode is not officially supported by Cadence, so use the link at your own risk. Our testing has shown it to provide significant performance improvements.

Limitations of this method include:

- This mode has the same limitation described in the previous section.

- If a Test circuit is used, this mode offers no performance enhancement.
- This mode does not work with remote hosts.

Using Template SPICE3 and the Open Simulator Interface spectre3.c

NOTE Using Template SPICE3 requires more processing time than the other SPECTRE templates. Using Template SPICE3 is not recommended, except when methods using SPECTRE, SPECTRE442, or SPECTRE443 are unavailable.

Using IC-CAP's Open Simulator Interface, a C-language *Translation Module* is provided that makes SPECTRE simulation capability available in IC-CAP. This module and instructions for performing SPECTRE simulations in IC-CAP are described here. For general information on the Open Simulator Interface, refer to the section "Adding a Simulator" in the *User's Guide*.

The IC-CAP/SPECTRE link uses UCB SPICE3 as the *template* simulator. When performing a SPECTRE simulation in IC-CAP, IC-CAP behaves as if it is performing a SPICE3 simulation. Therefore it generates an input deck in SPICE3 format, calls the simulator and reads back a binary raw data file in SPICE3 format. Through the Open Simulator Interface, the call to the simulator is actually calling the executable version of the C-language *Translation Module, spectre3.c.* This executable, called *spectre3,* translates the SPICE3 input deck to a SPECTRE input format, calls SPECTRE to perform the simulation, then translates the SPECTRE format binary raw data file to SPICE3 format which is read by IC-CAP. The source code file *spectre3.c* is located in the *$ICCAP_ROOT/src* directory.

NOTE When using SPECTRE, the CDS_LICENSE_DIR environment variable must be set. This variable contains the directory path for the license file required by the SPECTRE simulator. Refer to the SPECTRE Reference Manual for detailed procedures on installing the SPECTRE simulator.

NOTE SPECTRE does not support a secondary sweep in the DC specification. For DC simulations, set the System Variable MAX_DC_SWEEPS to 1 so that IC-CAP generates a separate input deck for every point in the secondary sweep, if it exists.

NOTE If you set the SPECTRE variable SPECTRE_DEFAULTS in your system startup file, for example, the *.profile* file, do not use the –E option. Use the following syntax:

```
SPECTRE_DEFAULTS   +l %C.r.out -f psfascii
```

To set up SPECTRE simulation capability in IC-CAP:

1. Add the *spectre* simulator to the *usersimulators* file in the directory *$ICCAP_ROOT/iccap/lib*, as shown next.
   ```
   spectre spice3 /<your path>/spectre3
   "<host_machine_name>" CANNOT_PIPE
   ```
2. The *host_machine_name* is the host computer for the SPECTRE simulations. This name can be left blank ("") if SPECTRE and IC-CAP are running on the same computer. Since SPECTRE does not have the ability to perform piped simulations in IC-CAP, the CANNOT_PIPE flag must always be set, as shown in the above example.
3. Make the following change to the *spectre3.c* program to customize it for your environment:
   - In the *main* routine, specify the full pathname of the actual SPECTRE simulator on your system.
4. Compile the translation module using the following command:
   ```
   cc -o spectre3 spectre3.c -lm
   ```
5. Move the executable file, *spectre3* to a permanent location such as *$ICCAP_ROOT/bin*. The location must match the path specified in the *usersimulators* file.
6. In IC-CAP, set the SIMULATOR variable to *spectre* or specify *spectre* with the *Select Simulator* command in the IC-CAP Tools Menu.

The following files are generated in your home directory when running SPECTRE simulations in IC-CAP:

- *spectre.cki* - SPECTRE format circuit description deck file translated from the SPICE3 circuit description deck.
- *spectre.raw* - SPECTRE formatted binary raw data output file generated by a SPECTRE simulation.
- *spectre.log* - Output print file generated by a SPECTRE simulation.

spectre.raw and *spectre.log* are automatically removed from your home directory after the simulation is completed in IC-CAP.

NOTE

Some of the new models implemented in SPECTRE use slightly different syntax for the model statement than they would for SPICE3. This difference will not be accounted for by the translator; you must change the model statement in the Circuit Description folder before simulating. The following examples show how the model statement would read for the MM9 and BSIM3 models:

```
model <name> mos902 type=n <parameters>
model <name> bsim3 type=n <parameters>
```

5 Saber Simulator

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This chapter describes the details of using the Saber simulator with IC-CAP. For general information on IC-CAP simulation, refer to Chapter 6, "Simulating," in the *User's Guide*.

The Saber simulator, developed by Analogy, Inc., analyzes analog, digital, event-driven analog and mixed-mode systems.

IC-CAP supports these Saber simulator features:

- Vary command for unlimited sweeps and simulation at multiple operating points
- DC Operating Point Analysis used with DC Transfer, AC Frequency, and Transient Analysis
- Options for each type of analysis (these options must be specified in the IC-CAP Variables Table)
- Parameter sweeps
- Alter command (For details, refer to "The Alter Command" on page 299)
- Hierarchical simulation
- Remote simulation

IC-CAP supports other Saber features as follows. (*Limited support* includes workarounds to achieve desired results that may not be in an ideal format.)

- MAST capabilities.
  - Limited support for the syntax required for model and element development. This can be done in a separate file and included in the Circuit Description using the MAST syntax:

    ```
    <filename
    ```

    where filename is the name of the file that contains the template description of the model or element under development.
  - IC-CAP does not support stimulus conversion to collect data on non-electrical nodes
- Limited support for noise analysis, Fourier analysis, distortion analysis, mixed-mode simulation, and mixed technology simulation. This includes simulations involving non-electrical types such as pressure, revolutions per minute, and torque.

IC-CAP does not support digital state type stimulus and response for mixed-mode simulation. Hypermodels must be used to convert digital states to analog signals.

The Saber simulator supports the following analysis types:

- DC
- AC
- Transient
- Capacitance Voltage (CV)
- 2-Port (S,H,Y,Z,K,A parameter)
- Time-Domain Reflectometry (TDR)

Saber Simulation Example

The circuit description is predefined for all IC-CAP configuration files. Enter this description if a new model is being defined; edit the description to fit specific needs. The syntax is identical to the syntax used for describing circuits in a typical Saber simulation deck.

This simulation example will use the IC-CAP supplied Model *sabernpn.mdl*.

1. Select the simulator by choosing **Tools > Options > Select Simulator > saber**. Choose **OK**.
2. Choose **File > Open > sabernpn.mdl**. Choose **OK**.
3. View the circuit description by clicking the **Circuit** tab.

   The circuit description is shown in Figure 12. This deck describes the circuit (in this case, a single device) to be used in the simulation.
4. To view the input and output for the fearly setup, click the **DUTs-Setups** tab and select **fearly**;

   The Measure/Simulate folder appears with the inputs vb, vc, ve, and vs, and the output ic. The vc input specifies a voltage source at node C that sweeps linearly from 0 to 5V in 21 steps. The ic output specifies that current at node C be monitored.

   In the Plots folder, icvsvc is specified so that the results of the simulation can be viewed graphically.
5. To simulate, click the **Simulate** button in the Measure/Simulate folder. The Status line displays Simulate in progress.

   When the simulation is complete, the Status line displays IC-CAP Ready.
6. To view the results of the simulation, display the Plots folder and click **Display Plot**. The plot displays measured data represented by solid lines and simulated data represented by dashed lines.

NOTE

For syntax examples of running a remote simulation, refer to "Remote Simulation Examples" in the *User's Guide*.

```
# Saber NPN Device
q..model sabernpn= (IS=le-16,
TYPE= n,
BF = 100,
NF  = 1,
VAF = 1000,
IKF = 10,
ISE = 0,
NE = 1.5,
BR = 1,
NR = 1,
VAR = 1000,
IKR = 10,
ISC = 0,
NC = 2,
RB = 0,
IRB = 10,
RBM = 0,
RE = 0,
RC = 0,
XTB = 0,
EG = 1.110,
XTI = 3.000,
CJE = 0,
VJE = 750m,
MJE = 333m,
TF = 0,
XTF = 0,
VTF = 1000,
ITF = 0,
CJC = 0,
VJC = 750m,
MJC = 333m,
XCJC = 1.0,
TR = 0,
CJS = 0,
VJS = 750m,
MJS = 0,
FC = 500.0m)
q.qckt C B E S= model = sabernpn, AREA = 1.0
```

Figure 12 MAST Circuit Description Deck for an NPN Bipolar Transistor

Piped and Non-Piped Saber Simulations

Non-piped Saber simulations are identical to non-piped SPICE simulations. However, there are differences between the 2 types of piped simulation. A piped simulation in Saber does the following:

1. Read the input deck from a file upon start up of the simulator
2. Read in the analysis commands from a pipe connected to *standard input*
3. Perform the simulation
4. Send the text output to a pipe connected to *standard output*
5. Save the output data to files

Saber is restarted if any topological changes are made to the circuit description. If changes are made which do not affect the topology of the circuit, such as changed parameter values, then alter commands are used and the simulator is not restarted.

Syntax: Non-Piped simulations

This section describes the argument syntax required to invoke the template simulator. This information is needed when writing the user translation module, since these are the arguments supplied by IC-CAP when it calls the translation module. For information on the translation module and adding a simulator, refer to "Adding a Simulator" in the *User's Guide*.

The command format for a Saber non-piped simulation is as follows:

```
saber -b deckfile
```

where:

-b specifies batch mode.

deckfile is the input file name. Saber will read *deckfile* as the input deck file containing the circuit description and *deckfile* as the command file containing the analysis statements.

The textfile is written to a file called *deckfile*.out.

The rawfile information is written to 2 files, called the control file and the data file. The control file is named *deckfile*.p1.*suffix* and the data file is named *deckfile*.p2.*suffix* where *suffix* is a keyword assigned by Saber according to the analysis being performed. Refer to the Saber User's Manual for more information.

Syntax: Piped simulations

The command format for a Saber piped simulation is as follows:

```
saber -c deckfile
```

where:

-c specifies the Saber command mode.

deckfile is the input deck file containing the circuit description.

Saber reads the analysis commands through *standard input.*

The textfile is written to a file called <*deckfile*>.*out.*

The rawfile is written to a file called <*deckfile*>.*p1.*<*suffix*> where *suffix* is a keyword assigned by Saber according to the analysis being performed. Refer to the *Saber User's Manual* for more information.

Saber Parameter Sweeps

NOTE The LSYNC sweep is not supported with the Saber simulator.

When using the Saber simulator, IC-CAP allows parameter sweeps of only parameters and Saber global variables, such as the global variable for temperature called TEMP. Like SPICE-type simulators, specifying parameter sweeps for devices and circuits is done the same way. Parameter names must be entered in the Name field of the Input table exactly as they appear in the Parameters table. An input for vto, with Mode set to P, is added to the *nmos2/short/idvd* setup, as shown in the following figure.

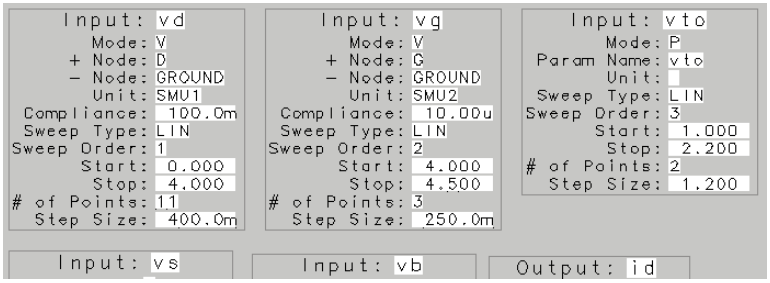

Figure 13 Saber Parameter Sweep Setup Example

Figure 14 shows the resulting plot.

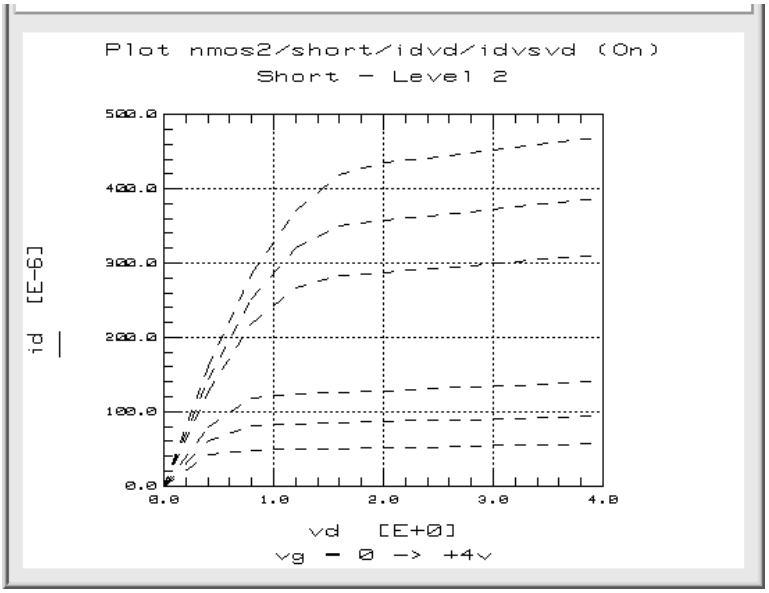

Figure 14 Saber Parameter Sweep Plot Example

For additional information on sweeping parameters, refer to "Specifying Parameter or Variable Sweeps" in the *User's Guide*.

The following sections of this chapter describe in more detail each of the steps in these simulation overview examples.

The Alter Command

An alter command temporarily changes the value of any element or parameter in a MAST template. It is used to make a change in a template description so that a simulation can be re-executed without reloading the original circuit. The alter command cannot be used to make a change that modifies the topology of a design.

Alter commands are used in IC-CAP Saber simulations when the Circuit Description and Setup information, other than the sweep limits, remain unchanged from the previous simulation.

If only parameter values in the Device Parameters table or Model Parameters table are changed, IC-CAP will not restart the Saber simulator and reload the circuit. Instead, IC-CAP generates alter commands for every parameter, then re-executes the simulation commands. The *USE_ALTER* variable can be specified and set to *No* to override this behavior. In this case, Saber is restarted with every simulation whether or not the Circuit Description or Setup was changed. If the *USE_ALTER* variable does not exist, IC-CAP behaves as if the variable were set to *Yes*.

After a successful simulation, if a resistor is changed from a non-zero to zero value, Saber collapses the nodes. This causes an *implicit* topological change in the circuit that is not recognized by IC-CAP since the Circuit Description or Setup information has not been changed. Turn the *USE_ALTER* variable off by setting it to *NO* to allow IC-CAP to restart the Saber simulator and reload the altered circuit.

Circuit Model Description

This section discusses the circuit description for the Saber simulator.

Selecting Simulator Options

Saber simulation options are not specified in the circuit description, but rather in the analysis command line. Saber simulator options are set using the *SABER_OPTIONS* variable in the Setup, DUT or System variable tables.

Enter the options in the *Value* section of the variable exactly as they should appear in the Saber command string. For example, to perform a transient simulation from 0 to 0.8 nsec in 10 psec steps, the Saber command generated in IC-CAP is:

```
tr(ts le-11, te 8e-10, tb 0)
```

To specify that all step sizes be fixed instead of variable, append the following option to the Saber command:

```
steps fix
```

To do this in IC-CAP, specify the options command *steps fix* in the value field of the *SABER_OPTIONS* variable. Simulation now performs the following transient analysis command:

```
tr(ts le-11, te 8e-10, tb 0, steps fix)
```

The *SABER_OPTIONS* variable can be specified in a variable table at any level. However, it is important to note that a *SABER_OPTIONS* variable specified in the DUT, Model or System variable tables is used by all simulations executed below that level. For example, if a *SABER_OPTIONS* variable is specified in the DUT variable table, every Setup under that DUT will use the specified option. This may result in simulation errors because 1 particular option may not be valid for every type of analysis being specified in the DUT.

Any number of options can be specified in the *SABER_OPTIONS* variable; they must be separated by a comma.

A Saber analysis in IC-CAP is always preceded by a DC operating point analysis. This DC command can also contain options and can be specified using the *SABER_DC_OPTIONS* variable.

Refer to Saber manuals for available options and corresponding syntax for each simulation type. Invalid options entered into the *SABER_DC_OPTIONS* and *SABER_OPTIONS* variables cause the simulation to fail.

Entering Circuit Descriptions

Circuit descriptions contain templates of devices and components, as well as node connections and model descriptions written in the MAST modeling language. All model parameter names must be specified when defining models. Circuit descriptions can also be read into the IC-CAP Circuit Editor from a file that already contains a description. You must enter circuit descriptions using valid model names and valid parameter names for the particular model being used.

Enter circuit descriptions for a Saber input deck with the Circuit Editor. IC-CAP contains a parser for descriptions written in the MAST modeling language.

There are 2 types of Saber circuit editor descriptions: devices and templates. Syntax rules for each type are described in the following sections.

Device Model Descriptions

A device model is used to characterize a single element of any type. This element can be predefined in the Saber library or defined by the user using the MAST modeling language.

A device model description requires a model definition written in the MAST modeling language and an element statement that calls a defined model.

A model description specifies the values of a device model that describes a particular element. When a parameter is not specified, the default value in the model template is used and the parameter does not appear in the IC-CAP Parameters table. The general form of the model definition is:

```
ENAME..model MNAME = (PNAME1=PVAL1, PNAME2=PVAL2,
...PNAMEX=PVALX)
```

where

ENAME is the name of the element template

MNAME is the user-specified name of the model being defined

PNAME is a parameter name for the particular model type

PVALs are the corresponding parameter values

The general form of the element statement that calls the device model is:

```
ENAME.DNAME NNAME1 NNAME2 ...NNAMEN = model = MNAME,
DPAR1 = DVAL1, DPAR2 = DVAL2 ...DPARN = DVALN
```

where

ENAME is the element template name

DNAME is the device name

NNAME specifies a node name

MNAME is the name of the model being referenced

DPAR is a predefined DUT parameter name

DVAL is the corresponding DUT parameter value

A sample element statement in the MAST modeling language is:

```
q.qckt C B E S = model = sabernpn,AREA = 1.0
```

where

q is the element template name defined in the Saber component library

qckt is the user-specified device name

C, *B*, *E*, and *S* are the node names

sabernpn is the model name. The model corresponding to this model name must be defined in the circuit description before the reference is made.

AREA is a DUT parameter of this model with an assigned value of *1.0*

As in Saber, a line ending with a comma is continued on the next line.

Template Descriptions

A template is used to characterize a circuit that contains more than 1 device. The syntax for defining a template is identical to that of the MAST modeling language. A template can be defined as either an *element* template or a *model* template. The general form of the first line of a template *element* definition is:

```
element template TEMPNAME NNAME1 NNAME2 ...NNAMEN = PAR1,
PAR2, ...PARN
```

where

TEMPNAME is the template name

NNAME is a node name of the external node of the template. External nodes are used to connect the template to another circuit.

PAR is the name of the parameter passed into the template

The general form of the first line of a template *model* definition is:

```
element template TEMPNAME NNAME1 NNAME2 ...NNAMEN = model
```

where

TEMPNAME is the template name

NNAME is the node name of the external node of the template. External nodes are used to connect the template to another circuit.

The body of a model definition defines the model parameters. For more information on writing templates, refer to the Saber *MAST Reference* manual.

When writing a template for model development within IC-CAP, the recommended procedure is to define the template in an external file and include this file in the IC-CAP circuit description using the MAST nomenclature <*filename*> to include a file. This minimizes the changes to be made in the IC-CAP Circuit Description and thereby increases the rate of model development because changes in the external template file will immediately be recognized in IC-CAP.

Non-Numeric Parameter Values

Saber allows non-numeric values for a number of parameters in predefined templates. The MOS model parameter *type* is 1 example. This parameter can take on the value of *_n* for an nmos device and *_p* for a pmos device.

When a Saber input parameter is in alpha format, it does not appear in the IC-CAP Parameters table but is still present in the input deck and passed to the simulator for analysis.

Node Names

Saber accepts alphanumeric names as well as numbers to represent nodes. There is no limit to the number of characters allowed in a node name (the command line has a limit of 1024 characters).

Test Circuits and Hierarchical Simulations

When characterizing a circuit, it is often necessary to add circuitry around a circuit or device to model the actual measurement Setup. IC-CAP provides a Test Circuit Editor to allow modeling of this additional bias circuitry. Select the DUT from the DUT/Setup panel. Click the Test Circuit tab and enter the test circuit description in the same manner you would enter a Circuit Description. The test circuit

definition should include a call to the device or template circuit defined in the Circuit Editor, as well as the additional circuitry needed to model the external parasitics of the measurement Setup.

NOTE

When you define a test circuit, the DUT Parameters table contains the values specified in the test circuit specification. Regardless of the name entered in the TEMPNAME field of the template definition statement, IC-CAP uses the name of the DUT being simulated when the simulator input deck is built.

Template circuit and device model specifications can be called from inside another Model. This allows you to perform *hierarchical simulations* to study a circuit at different levels. For example, assume you have defined 3 Models, *model1*, *model2*, and *model3*. *Model1* has a circuit model description that is a device definition. The circuit model description for *model2* is a template circuit definition at the gate level that includes a call to *model1* in a device call statement. And, the circuit model description for *model3* is a template circuit definition that includes a call to *model2* in a subcircuit call statement. When you simulate a Setup in *model3*, IC-CAP traverses the Model hierarchy and uses the circuit model description defined in *model3*, which includes calls to *model1* and *model2*. The syntax for calling a device model is identical to that described in the *Device Model Specifications* section above.

The general form of the device call is:

```
ENAME.DNAME NNAME1 NNAME2 ...NNAMEN = model MNAME,
DPAR1 = DPAR1, DPAR2 = DVAL2 ...DPARN = DVALN
```

Calling a template specification allows you to insert an entire template into a circuit as if it were a single component. The call requires a syntax identical to that used in the MAST modeling language. The general form of the template element call is:

```
TEMPNAME.TNAME NNAME1 NNAME2 ...NNAMEN = TPAR1 = TPARVAL1,
TPAR2 = TPARVAL2, ...TPARN = TPARVALN
```

where

TEMPNAME is the name of the template previously described by a template definition. This template definition could exist in a different Model.

TNAME is the user specified name given to this particular instance of the template described by TEMPNAME.

NNAMEs represent the node names of the calling circuit that connect to the external nodes of the template. The calling circuit's node names need not be the same as the external nodes of the template. The order in which you specify these nodes is the order in which they are connected. The same number of nodes as declared in the template definition must be specified.

TPARs are predefined template parameter names. These parameters are defined in the template definition. *TPARVALs* are the corresponding values of the template parameters.

A hierarchical simulation, in which a template in 1 model references a device defined in a different model, requires the use of a MAST *external* declaration in the template definition. For example, assume a MOS device model (Saber template *m* named *nmos2),* which is called in the body of a circuit template called *inverter* in another model. This *inverter* template must include the following declaration in order for the *nmos2* device model to be recognized.

```
external m..model nmos2
```

The complete template for the inverter circuit is:

```
template inv A B C D E F
electrical A, B, C, D, E, F
{
external m..model nmos2
m.minv A B C D = model = nmos2, l = 10u, w = 10u
m.mload E F A D = model = nmos2, l = 10u, w = 10u
}
```

The external declaration does not need to be added when a template calls another template.

Refer to the Saber manuals for complete syntax and rules of the MAST modeling language.

Saber Libraries

The Saber library of components and templates includes the SPICE components as well as the components developed by Analogy, Inc. Refer to the Saber manuals for a list of supported simulator components, higher level templates and the required specification formats.

Saber Input Deck Comments

To indicate comments in the Saber simulator input deck, start an input line with the pound symbol (#). This denotes a comment in the circuit model description or in the input file of the Simulation Debugger.

NOTE

The *SABER_DATA_PATH* environment variable must be set. This variable contains the directory paths for the executable files and libraries required by the Saber simulator. Refer to the *Saber Reference Manual* for installation procedures.

5 Saber Simulator

6 MNS Simulator

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This chapter describes the details of using the MNS simulator with IC-CAP. For general information on IC-CAP simulation, refer to Chapter 6, "Simulating," in the *User's Guide*.

IC-CAP supports the following Microwave Nonlinear Simulator (MNS) features:

- DC, Small Signal AC, Small Signal S-Parameter, and Transient analysis options
- Parameter sweeps for device and circuit simulation
- Temperature sweeps
- Hierarchical simulation
- Variables
- Constants
- Expressions

The MNS Optimizer features are not currently supported in IC-CAP. IC-CAP optimization (different from the MNS Optimizer) of simulated data to target data is supported.

The MNS simulator supports the following analysis types:

- DC
- AC
- 2-port
- Transient
- Noise
- Capacitance Voltage (CV)
- Time-Domain Reflectometry (TDR)
- Harmonic Balance

NOTE IC-CAP does not add extra circuitry in order to perform a 2-port simulation since this is a standard type in MNS.

MNS Simulation Example

The circuit description is predefined for all IC-CAP configuration files. Enter this description if a new model is being defined; edit the description to fit specific needs. The syntax is identical to the syntax used for describing circuits in a typical MNS simulation deck.

This MNS simulation example will use the IC-CAP supplied Model *mnsnpn.mdl*.

1 Select the simulator by choosing **Tools > Options > Select Simulator > mns**. Choose **OK**.

2 Choose **File > Open > mnsnpn.mdl**. Choose **OK**.

3 View the description by clicking the **Circuit** tab.

The circuit description is shown in the following figure. This deck describes the circuit (in this case, a single device) to be used in the simulation.

```
options ascii=no
model npnbjt bjt NPN=yes \
IS=4.015e-16 BF = 87.01 \
NF = 0.9955 VAF = 84.56 \
IKF = 0.01195 ISE = 3.405E-14 \
NE = 1.594 BR = 10.79 \
NR = 1.002 VAR = 9.759 \
IKR = 0.0237 ISC = 1.095E-15 \
NC = 1.1 RB = 9.117 \
IRB = 0.001613 RBM = 5.62 \
RE = 1.385 RC = 9.292 \
XTB = 1.7 EG = 1.11 \
XTI = 3 CJE = 1.312E-12 \
VJE = 1.11 MJE = 0.3475 \
TF = 5.274E-11 XTF = 5.625 \
VTF = 2.678 ITF = 0.02382 \
PTF = 154.1 CJC = 1.396E-12 \
VJC = 0.4511 MJC = 0.1924 \
XCJC = 0.3 TR = 1E-09 \
CJC = 9.985E-14 VJS = 0.8137 \
MJS = 0.3509 FC = 0.5
npnbjt:qckt C B E S
```

Figure 15 MNS Circuit Description Deck for an NPN Bipolar Transistor

4 To view the input and output for the fearly setup, click the **DUTs-Setups** tab and select **fearly**.

The Measure/Simulate folder appears with the inputs vb, vc, ve, and vs, and the output ic. The vc input specifies a voltage source at node C that sweeps linearly from 0 to 5V in 21 steps. The ic output specifies that current at node C be monitored.

In the *Plots* folder, *icvsvc* is specified so that the results of the simulation can be viewed graphically.

5 To simulate, click the **Simulate** button in the Measure/Simulate folder. The Status line displays **Simulate in progress**.

When the simulation is complete, the Status line displays IC-CAP Ready.

6 To view the results of the simulation, display the *Plots* folder and click **Display Plot**. The plot displays measured data represented by solid lines and simulated data represented by dashed lines.

NOTE Phase information from the sin input cannot be included in the netlist.

NOTE For syntax examples of running a remote simulation, refer to "Remote Simulation Examples" in the *User's Guide*.

The Simulation Debugger

When using MNS with the Simulation Debugger to perform an IC-CAP simulation (as opposed to a manual simulation), an output text file consists of only the computational analysis information. An example of a typical AC analysis output text file is as follows:

```
MNS (ver. 03.00 -- 12 Feb 2004)
Copyright Agilent Technologies, 2004
AC ac1[1] <baaa07774>   freq=(1 kHz->10 MHz)
Time required for ac1[1] was 0.30 seconds.
```

This file does not include the resulting data. To generate a more informative output text file, change the *ascii* option in the Input File from *ascii=no* to *ascii=yes* and perform a manual simulation. An output text file that includes the simulated output data values is produced. The *ascii* option is set to *no* by IC-CAP before every simulation so that the binary raw data file is generated by MNS. IC-CAP needs the binary raw data file to read the resulting simulation data. However, this data is not needed for a manual simulation.

MNS version 4.0 requires that the option *nutmeg* be set to *yes* to cause MNS to generate the binary raw data file required by IC-CAP. If the *nutmeg* option is not specified, the default is *nutmeg* = *yes*. If you set *nutmeg* = *no,* MNS will generate an output data format that IC-CAP cannot understand.

Piped MNS Simulations

Specifying CAN_PIPE (the default) in your *usersimulators* file for MNS enables IC-CAP to take advantage of the tune mode built into the MNS simulator. This mode permits changing parameters of a simulation without requiring the simulator to be relaunched. This greatly reduces the time required for an optimization which has all simulated targets within 1 setup. Whenever the setup is changed, the simulator is stopped and restarted with the new resulting netlist. Thus, an optimization that has multiple simulated targets from different setups must stop the simulator and restart it at each iteration as it switches between setups. The performance of this second scenario is the same as if the non-piped mode were used.

Non-Piped MNS Simulations

Non-piped MNS simulations are identical to non-piped SPICE simulations. Execute a simulation with the Simulation Debugger ON to perform a non-piped simulation. MNS is capable of performing piped simulations, which enables you to turn the Simulation Debugger OFF without requiring that MNS be restarted for every simulation.

Syntax: Non-piped simulation

This section describes the argument syntax required to invoke the template simulator. This information is needed when writing the user translation module, since these are the arguments supplied by IC-CAP when it calls the translation module. For information on the translation module and adding a simulator, refer to "Adding a Simulator" in the *User's Guide*.

The command format for an MNS non-piped simulation is as follows:

```
mns -r rawfile deckfile
```

where:

deckfile is the input deck file containing the circuit description and analysis commands.

rawfile is the output binary data file.

The output text file, which normally is sent to *standard output* is redirected by IC-CAP to a file. This file is displayed in the Output table of the Simulation Debugger if it is on.

MNS Parameter Sweeps

When using the MNS simulator in IC-CAP, the method of specifying parameter sweeps differs between performing single device simulations and circuit simulations.

NOTE

When performing parameter sweeps, the name of the parameter to be swept must be recognized by MNS, since the analysis is performed from within the simulator. This means that the global declaration must be used within the MNS circuit description. Simply adding the parameter name to the Variables table results in a failed simulation.

Device Simulation Parameter Sweep

To sweep a parameter in an MNS device simulation:

1. Add an input specification of mode P to the Setup. Enter the name of the parameter as it appears in the Parameters table.
2. Enter the sweep type and values.

The Device Simulation Parameter Sweep example uses the *mnsnpn.mdl* model with an input of mode P to the *fearly* setup. This input specifies a linear sweep of the parameter from 200.0e–15 to 230.0e–15 amperes in steps of 15.0e–15 amperes.

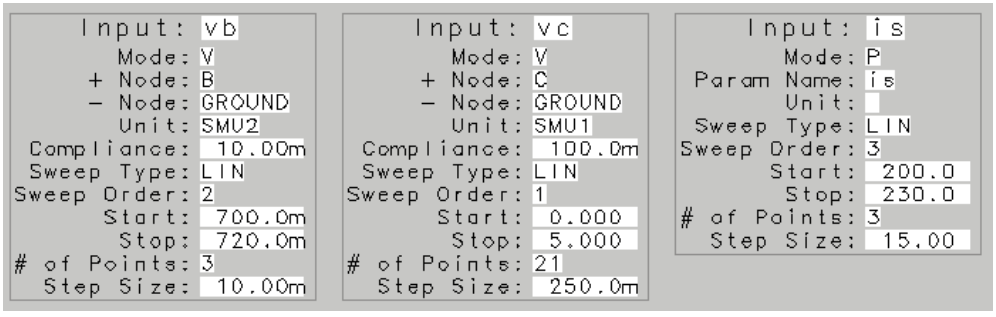

Figure 16 MNS Device Simulation Parameter Sweep Setup Example

During the simulation, IC-CAP generates the following input deck.

```
; Simulation Input File options ascii=no
model mnsnpn bjt npn=yes\
is=4.015E-16\
bf = 60 \ nf = 0.9955\
 vaf = 84.56\
 ikf = 0.01195 \
 ise = 3.405E-14 \
 ne = 1.594 \
 br = 10.79 \
 nr = 1.002 \
 var = 9.759 \
 ikr = 0.00237 \
 isc = 1.095E-15 \
 nc = 1.1 \
 rb = 9.117 \
 irb = 0.001613 \
 rbm =5.62 \
 re = 1.385 \
 rc = 9.292 \
 xtb = 1.7 \
 eg = 1.11 \
 xti = 3 \
 cje = 1.312E-12 \
 vje = 1.11 \
 mje = 0.3475 \
 tf = 5.274E-11 \
 xtf = 5.625 \
 vtf = 2.678 \
 itf = 0.02382 \
 ptf = 154.1 \
 cjc = 1.396E-12 \
 vjc = 0.4511 \
 mjc = 0.1924 \
 xcjc = 0.3 \
 tr = 1E-09 \
 cjs = 9.985E-14 \
 vjs = 0.8137 \
 mjs = 0.3509 \
 fc = 0.5
mnsnpn:devckt 1 2 3 4 \
area = 1
; START SOURCES
ivs:V2GROUND 2 0 vdc=0
ivs:V1GROUND 3 0 vdc=0
ivs:V3GROUND 3 0 vdc=0
ivs:V4GROUND 4 0 vdc=0
; END SOURCES
stim:swp1 start=0 stop=5 step=0.25
stim:swp2 start=0.7 stop=0.72 step=0.01
stim:swp3 start=200a stop=230a step=15a
dc:dc1 stim=swp1 var="V1GROUND.vdc"
ct:ct1 an="dc1" stim=swp2 var="V2GROUND.vdc"
ct:ct2 an="ct1" stim=swp3 var="mnsnpn.is"
```

Circuit Simulation Parameter Sweep

Specifying a parameter sweep for a circuit simulation requires a different approach from a parameter sweep for a device simulation.

To sweep a parameter in an MNS circuit simulation:

1. Specify a global variable in the MNS circuit description and set it to an initial value.
2. Set the value of the parameter in the circuit description equal to the global variable name.
3. Add a variable in IC-CAP with the same name as the global MNS parameter.
4. Add an input specification of mode P to the Setup.
5. Enter the global variable name in the Name field of the Input table.
6. Enter the sweep type and values.

Example Circuit Simulation Parameter Sweep

The Circuit Simulation Parameter Sweep example, uses the model mnsopamp.mdl. The following line is added to the circuit description:

global RC1_r=4352

This complete circuit description is shown below.

```
; Simulation Input File in MNS Input Deck Format
options ascii=no
define opamp1 (2 3 4 6 7 )
global RC1_r=4352
;Internal OpAmp circuit
;using Boyle-Pederson Macro Model
;Input differential amplifier
npn1:Q1 10 2 12
npn2:Q2 11 3 13
model npn1 bjt npn=yes is = 8E-16 bf = 52.81
model npn2 bjt npn=yes is = 8.093E-16 bf = 52.66
r:RC1 7 10 r=RC1_r
r:RC2 7 11 r=4352
c:C1 10 11 c=4.529E-12
r:RE1 12 14 r=2392
r:RE2 13 14 r=2392
r:RE 14 0 r+7.27E+06
c:CE 14 0 c=7.5E-12
; Power dissipation modeling resistor
r:RP 7 4 r=1.515E+04
; 1st gain stage
vccs:GCM 0 15 14 0 gm=1.152E-09
vccs:GA 15 0 10 11 gm=0.0002298
r:R2 15 0 r=1E+05
; Compensation capacitor
c:C2 15 16 c=1E-11
; 2nd gain stage
vccs:GB 16 0 15 0 gm=37.1
r:RO2 16 0 r=489.2
dmod1:D1 16 17
dmod1:D2 17 16
model dmod1 diode is = 3.822E-32
r:RC 17 0 r=0.0001986
vccs:GC 0 17 6 0 gm=5034
; Output circuit
r:RO1 16 6 r=76.8
dmod2:D3 6 18
dmod2:D4 19 6
model dmod2 diode is = 3.822E-32
ivs:VC 7 18 vdc=1.604
ivs:VE 19 4 vdc=3.104
; Input diff amp bias source
ics:IEE 14 4 idc=2.751E-05
end opamp1
```

In this example, the value of r:RC1 is set to *RC1_r*. You must also add a variable called RC1_r to the IC-CAP model variables table and set the variable to a value, such as,

4.000K. In the setup *mnsopamp/inv_amp/B_P_macro* add an input called *RC1_r*. The Inputs table is shown in the following figure.

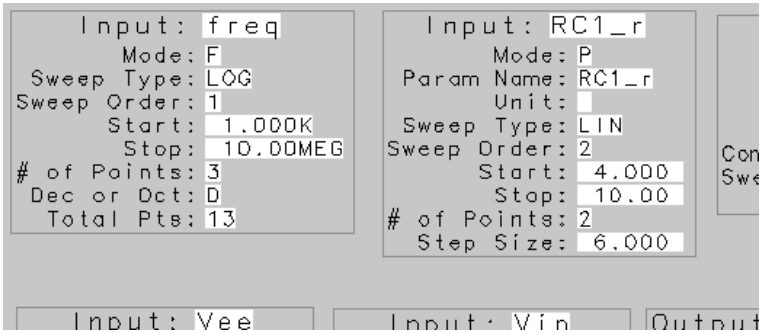

Figure 17 MNS Circuit Parameter Sweep Setup Example

For additional information on sweeping parameters, refer to "Specifying Parameter or Variable Sweeps" in the *User's Guide*.

The following sections of this chapter describe in more detail each of the steps in these simulation overview examples.

Circuit Model Description

This section explains the circuit descriptions for the MNS simulator.

Selecting Simulator Options

MNS simulation options are specified using the MNS_OPTIONS variable in the Setup DUT or System Variable tables. Enter the options in the value section of the variable exactly as they should appear in the MNS options command.

Entering Circuit Descriptions

The circuit description is entered into the IC-CAP Circuit Editor or the Test Circuit Editor. The circuit description includes the necessary definitions of devices, sources and components, as well as node connections and model descriptions. MNS accepts a netlist description that is different from SPICE and Saber simulators.

Parameter Table Generation

The circuit description is parsed by IC-CAP and specific model information (such as parameters and their corresponding values) as well as circuit component values are reflected in the Parameters table. Model parameters and component values specified in the circuit description entered in the Circuit Editor are saved in the Parameters table. Device parameters specified in the model call statement are saved in the DUT Parameters table—unless a Test Circuit is specified, in which case, parameter values specified in the test circuit description are saved in the DUT Parameters table.

Non-numeric Parameter Values

MNS allows non-numeric values for a number of parameters in predefined component definitions. One example is the BJT model parameter *npn*. This parameter can take on the value

of *yes* if it is an nmos device. Alpha format parameters do not appear in the IC-CAP Parameters table but do appear in the simulation input decks.

Circuit descriptions must be entered with valid model and parameter names for the particular model being used.

Node Names

MNS accepts alphanumeric names as well as numbers to represent nodes. There is no limit on the number of characters allowed in a node name; however, delimiters or non-alphanumeric characters are not allowed. Also, a node name that begins with a digit must consist only of digits.

Comments

To indicate comments in an MNS input deck, start an input line with a semicolon (;). All text on the line following the semicolon will be ignored.

NOTE MNS will treat the suffix *M* as *MEG* and *m* as *milli*, whereas IC-CAP parses both *M* and *m* as *milli*. When specifying a value multiplied by10^{-3} use *m*; when specifying a value multiplied by 10^{6} use *MEG*.

Device Model Descriptions

A device model is used to characterize a single MNS-defined element of any type. This specification requires a model definition that describes the device and an instance statement that calls the model definition.

The model description specifies the value of a device model that describes a particular element. When a parameter is not specified, the default value in the model is used. The general form of the model definition is:

```
model MNAME TYPE PNAME1 = PVAL1 PNAME2 = PVAL2...
```

where

MNAME is the model name. (Regardless of the model name entered into the MNAME field of the MNS model definition statement, IC-CAP substitutes this field with the name of the Model as it is called in the Model List when the simulator input deck is built.)

TYPE is a valid MNS element type.

PNAMEs are parameter names available for the particular model type.

PVALs are the parameter values.

A backslash immediately followed by a return (no space between the backslash and the return) at the end of a line indicates that the statement is continued on the next line This continuation character is often used for easier readability when specifying the model description.

The general form of the instance statement that calls the device model is:

```
TYPE :DNAME NNAME1 NNAME2...NNAMEN DPAR1 = DVAL1
DPAR2 = DVAL2...DPARN = DVALN
```

where

TYPE is the instance type descriptor. This field can contain either the MNS instance type name or a user-supplied model or subcircuit name.

DNAME is the device name.

NNAMEs denote node names.

DPAR is a predefined DUT parameter name.

DVAL is the specified DUT parameter value. Refer to the *MNS User's Guide* for DUT parameter names available for each model.

Subcircuit Model Descriptions

A subcircuit definition represents a circuit that contains more than 1 device. The syntax for defining a subcircuit is identical to the syntax used for the MNS input language.

The general form of the subcircuit definition is:

```
define SUBCKTNAME (NNAME1 NNAME2 ...NNAMEN)
parameters PAR1 = VAL1 PAR2 = VAL2 ...PARN = VALN
< body of subcircuit >
end SUBCKTNAME
```

where

SUBCKTNAME is the name of the subcircuit.

NNAMEs are the node names of the external nodes of the subcircuit. These external nodes are used to connect the subcircuit to another circuit.

*PAR*s are the names of the parameters passed into the subcircuit. These parameters are optional in a subcircuit definition.

If parameters are specified, the assigned default values *VAL* are also optional. A parameter is assigned to this default value if the parameter is not specified in the subcircuit call.

The body of the subcircuit contains element statements. It can contain calls to other subcircuits but it cannot contain other subcircuit definitions.

The subcircuit definition is completed using the *end* SUBCKTNAME statement.

Calling a subcircuit definition allows you to insert all instances specified within the subcircuit into the circuit. The call requires a syntax identical to the syntax used in the MNS input language for any instance statement. The general form of the instance statement is:

```
TYPE :INAME NNAME1 NNAME2....NNAMEN PAR1 = VAL1
PAR2 = VAL2......PARN = VALN
```

(While the syntax shown here is correct, passed parameters are ignored by IC-CAP.)

where

TYPE is the instance type descriptor. If a subcircuit is being called, this field would contain the subcircuit name denoted by *SUBCKTNAME*.

INAME is the instantiated name of the subcircuit.

NNAMEs denote node names.

PARs are the subcircuit parameter names.

VALs are the specified subcircuit parameter values.

The following is an example of a complete subcircuit definition and subcircuit call.

- Defined by the user in the Circuit folder:

```
options ascii=no
define opamp1 (2 3 4 6 7)
; Internal OpAmp circuit
; using Boyle-Pederson Macro Model
; Input differential amplifier
npn1:Q1 10 2 12
npn2:Q2 11 3 13
model npn1 bjt npn=yes is = 8E-16 bf = 52.81
model npn2 bjt npn=yes is = 8.093E-16 bf = 52.66
r:RC1 7 10 r=4352
r:RC2 7 11 r=4352
c:C1 10 11 c=4.529E-12
r:RE1 12 14 r=2392
r:RE2 13 14 r=2392
r:RE 14 0 r=7.27E+06
c:CE 14 0 c=7.5E-12
: Power dissipation modeling resistor
r:RP 7 4 r=1.515E+04
: 1st gain stage
vccs:GCM 0 15 14 0 gm=1.152E-09
vccs:GA 15 0 10 11 gm=0.0002298
r:R2 15 0 r=1E+05
; Compensation capacitor
c:C2 15 16 c=1E-11
; 2nd gain stage
vccs:GB 16 0 15 0 gm=37.1
r:RO2 16 0 r=489.2
dmod1:D1 16 17
dmod1:D2 17 16
model dmod1 diode is = 3.822E-32
r:RC 17 0 r=0.0001986
vccs:GC 0 17 6 0 gm=5034
; Output circuit
r:RO1 16 6 r=76.8
dmod2:D3 6 18
dmod2:D4 19 6
model dmod2 diode is = 3.822E-32
ivs:VC 7 18 vdc=1.604
ivs:VE 19 4 vdc=3.104
; Input diff amp bias source
ics:IEE 14 4 idc=2.751E-05
end opamp1
```

- Defined by the user in the Test Circuit folder:

```
;Inverting Amplifier
define inv_amp (1 2 3 4 6 7 )
opamp1:X1 2 3 4 6 7
r:Rf 6 2 r=1E+04
r:Rin 2 1 r=2000
r:Rgnd 3 0 r=0.001
end inv_amp
```

- Added by IC-CAP to the circuit description:

```
inv_amp:XCKT 1 2 3 4 5 6
; START SOURCES
ivs:V1GROUND 1
0 vdc=0 vac=1 ivs:V7GROUND 6 0 vdc=15
ivs:V5GROUND 4 0 vdc=-15 ; END SOURCES
r:RO2 2 0 100000
r:RO3 3 0 100000
r:RO5 5 0 100000
stim:swpfreq start=1000 stop=1e=07 dec=3
ac:ac1 stim=swpfreq var="freq"
```

For more information on MNS subcircuit definitions, refer to the *MNS User's Guide*.

MNS Input Language

The MNS Input Language, which describes circuit and simulator control statements, is different from the SPICE Input Language and the Saber Input Language (MAST). For information about the MNS input language, refer to the *MNS User's Guide*.

MNS Libraries

MNS contains a library of elements and components. For information about the MNS Libraries, refer to the *MNS User's Guide*.

7
ADS Simulator

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This chapter describes the details of using the Advanced Design System (ADS) Simulator with IC-CAP. For general information on IC-CAP simulation, refer to Chapter 6, “Simulating,” in the *User’s Guide*.

NOTE The PC version of IC-CAP supports ADS version 2002 or newer. Older versions of ADS can not be used with the PC version of IC-CAP.

IC-CAP supports the following ADS features:

- DC, Small Signal AC, Small Signal S-Parameter, and Transient analysis options
- Parameter sweeps for device and circuit simulation
- Temperature sweeps
- Hierarchical simulation
- Variables
- Constants
- Expressions
- Spectre circuit page

The ADS Optimizer features are not currently supported in IC-CAP. IC-CAP optimization (different from the ADS Optimizer) of simulated data to target data is supported.

The ADS simulator supports the following analysis types:

- DC
- AC
- 2-port
- Transient
- Noise
- Capacitance Voltage (CV)
- Time-Domain Reflectometry (TDR)
- Steady State Harmonic Balance

NOTE

2-port simulation with high frequency noise is supported to extract noise parameters such as noise figure, optimum source reflection coefficients, equivalent noise resistance data, minimum noise figure data, and equivalent noise temperature data.

IC-CAP does not add extra circuitry in order to perform a 2-port simulation since this is a standard type in ADS.

ADS Interfaces

IC-CAP provides two template names to interface to the ADS simulator's Circuit and Test Circuit pages—*hpeesofsim* uses native ADS simulator syntax and *spmodeads* uses spectre simulator syntax. Both interfaces use native ADS simulator syntax to specify the sweep and output requests.

To specify the *hpeesofsim* or *spmodeads* interface, usersimulators should have a line similar to the following:

```
hpeesofsim hpeesofsim $ADS_DIR/bin/iccapinterface "" CAN_PIPE
```

or

```
spmodeads spmodeads $ADS_DIR/bin/iccapinterface "" CAN_PIPE
```

The first field can be any name you choose, it will show up in your simulator list, and it can be used with the *SIMULATOR* variable.

Both the *hpeesofsim* and *spmodeads* lines shown above are in the usersimulators file by default.

When using the *spmodeads* interface, refer to "Circuit Model Descriptions" on page 276 in Chapter 4, "SPECTRE Simulator" for spectre syntax for the Circuit and Test Circuit pages.

Hardware and Operating System Requirements

The ADS Simulator on IC-CAP is supported on the following platforms:

- Linux RedHat Enterprise 4.0 or Linux Novell SUSE SLES 9
- Solaris 10
- Microsoft Windows XP or Microsoft Windows Vista.

Codewording and Security

The ADS Simulator is a secured program that requires, at a minimum, a license for the E8881 Linear Simulator to run. Depending on the type of simulation, additional licenses may be required.

Setting Environment Variables

Before running the ADS Simulator, set the environment variable *HPEESOF_DIR* on UNIX or *ADS_DIR* on Windows to point to the ADS Simulator's installation location.

- To set *HPEESOF_DIR* using the Korn Shell, add the following to your *~/.profile*.
  ```
  export HPEESOF_DIR=<ADS_install_directory>
  ```
- To set *HPEESOF_DIR* using the C Shell, add the following to your *~/.cshrc*.
  ```
  setenv HPEESOF_DIR <ADS_install_directory>
  ```
- To set *ADS_DIR* for Windows 2000, right click on **My Computer** and select **Properties**. Click on the **Advanced** tab. Then select **Environment Variables** and set *ADS_DIR* either for the local user or system wide, depending on your needs.
- To set *ADS_DIR* for Windows NT 4.0, right click on **My Computer** and select **Properties**. Click on the **Environment** tab. Then set *ADS_DIR* either for the local user or system wide, depending on your needs. You may need to log off and log back onto the computer for the new variable to be found by IC-CAP.

ADS Simulation Example

The circuit description is predefined for all IC-CAP configuration files. Enter this description if a new model is being defined; edit the description to fit specific needs. The syntax is identical to the syntax used for describing circuits in a typical ADS simulation deck.

This ADS simulation example will use the IC-CAP supplied Model *hpsimnpn.mdl*.

1 Choose **File > Examples > model_files / bjt / hpsimnpn.mdl**. Choose **OK**.

2 View the description by clicking the **Circuit** tab.

The circuit description is shown in the following figure. This deck describes the circuit (in this case, a single device) to be used in the simulation.

```
; Simulation Input File for BJT
options ascii=no
model npnbjt BJT NPN=yes \
Is=401.5a Bf = 87.01 \
Nf = 995.5m Vaf = 84.56 \
Ikf = 11.95m Ise = 34.05f \
Ne = 1.594 Br = 10.79 \
Nr = 1.002 Var = 9.759 \
Ikr = 23.7m Isc = 1.095f \
Nc = 1.100 Rb = 9.117 \
Irb = 1.613m Rbm = 5.620 \
Re = 1.385 Rc = 9.292 \
Xtb = 1.7 Eg = 1.110 \
Xti = 3.000 Cje = 1.312p \
Vje = 1.110m Mje = 347.5m \
Tf = 52.74p Xtf = 5.625 \
Vtf = 2.678 Itf = 23.82 \
Ptf = 154.1 Cjc = 1.396p \
Vjc = 451.1m Mjc = 192.4m \
Xcjc = 300m Tr = 1.00n \
Cjs = 99.85f Vjs = 813.7m \
Mjs = 350.9m Fc = 500.0m \
Tnom = 27
npnbjt:Q1 C B E S
```

Figure 18 ADS Circuit Description Deck for an NPN Bipolar Transistor

3 To view the input and output for the fearly setup, click the **DUTs-Setups** tab and select **fearly**.

The Measure/Simulate folder appears with the inputs vb, vc, ve, and vs, and the output ic. The vc input specifies a voltage source at node C that sweeps linearly from 0 to 5V in 21 steps. The ic output specifies that current at node C be monitored.

In the Plots folder, *icvsvc* is specified so that the results of the simulation can be viewed graphically.

4 To simulate, click the **Simulate** button in the Measure/Simulate folder. The Status line displays **Simulate in progress**. Under most configurations, the ADS status window will appear. For more information about these configurations, see "Piped ADS Simulations" on page 336.

When the simulation is complete, the Status line displays **Simulate Complete**.

5 To view the results of the simulation, right-click on **fearly**, then choose **Plots > icvsvc**. (This is a shortcut for displaying the plot from the *Plots* folder.) The plot displays measured data represented by solid lines and simulated data represented by dashed lines.

NOTE For syntax examples of running a remote simulation, refer to "Remote Simulation Examples" in the *User's Guide*.

The Simulation Debugger

When using ADS with the Simulation Debugger to perform an IC-CAP simulation (as opposed to a manual simulation), an output text file consists of only the computational analysis information. An example of a typical AC analysis output text file is as follows:

```
HPEESOFSIM (ver. 03.00 -- 12/14/01 09:28:45)
Copyright Agilent Technologies, 2004

CT ct1[1] </var/tmp/ICCAAa18727>   VBGROUND.Vdc=(700 mV->720 mV)

DC ct1[1].dc1[1/3] </var/tmp/ICCAAa18727>  VBGROUND.Vdc=700 mV  VCGROUND.Vdc=(0 V->5 V)

DC ct1[1].dc1[2/3] </var/tmp/ICCAAa18727>  VBGROUND.Vdc=710 mV  VCGROUND.Vdc=(0 V->5 V)

DC ct1[1].dc1[3/3] </var/tmp/ICCAAa18727>  VBGROUND.Vdc=720 mV  VCGROUND.Vdc=(0 V->5 V)

-------------------
Simulation finished.
-------------------
```

This file does not include the resulting data. To generate a more informative output text file, change the *ASCII_Rawfile* option in the Input File from *ASCII_Rawfile=no* to *ASCII_Rawfile=yes* and perform a manual simulation. An output text file that includes the simulated output data values is produced. The *ASCII_Rawfile* option is set to *no* by IC-CAP before every simulation so that the binary raw data file is generated by ADS. IC-CAP needs the binary raw data file to read the resulting simulation data. However, this data is not needed for a manual simulation.

ADS version 1.3 requires that the option *UseNutmegFormat* be set to *yes* to cause ADS to generate the binary raw data file required by IC-CAP. If the *UseNutmegFormat* option is not specified, the default is *UseNutmegFormat = yes*. If you set *UseNutmegFormat = no,* ADS will generate an output data format that IC-CAP cannot understand.

Piped ADS Simulations

Specifying CAN_PIPE (the default) in your *usersimulators* file for the ADS simulator enables IC-CAP to take advantage of the tune mode built into the ADS simulator. This mode permits changing parameters of a simulation without requiring the simulator to be relaunched. This greatly reduces the time required for optimizations to run. However, each setup requires a new simulator to be launched. By default, IC-CAP permits up to 3 ADS simulators to be running at once so that an optimization across as many as 3 setups can be completed in the fastest time possible. Certain large simulations may require a great deal of system resources and having 3 simulations currently active can degrade system performance. If you encounter this problem, you can set the MAX_PARALLEL_SIMULATORS system variable to 1 or 2. If your system can handle more than 3 simulators in parallel and you need to optimize across more than 3 setups at a time, the value of MAX_PARALLEL_SIMULATORS can be increased.

When CAN_PIPE mode is used, the ADS simulator will bring up a status window during simulation. The first time the simulator is launched it can take several seconds for this window to appear. Once it is open, successive simulations will attach to the same status window. Each time a new setup is simulated, a new simulator must be started. There is a certain start-up delay associated with each invocation. This will be much shorter than the very first invocation which needed to launch the status window. Successive simulations of a setup which has been previously simulated will return in the shortest time as the simulator does not need to be reinvoked.

Opening the Simulation Debugger will terminate all running simulators, and close the ADS status window. Simulations done with the Simulation Debugger window open are performed in non-piped mode and thus the ADS status window is not opened.

In situations when you want to use the *$mpar* or *$dpar* feature in *#echo* lines for MNS and ADS netlists, you *must* enter names properly. The proper ADS name syntax is a dot-separated name, such as *NPN.Bf*. If you fail to use a proper name, simulations

will yield incorrect results when you try to use the simulator in CAN_PIPE mode. If names cannot be revised, use CANNOT_PIPE.

This was especially problematic for userdefined models requiring many *#echo* lines using the *$mpar* feature in order for IC-CAP to parse it properly. This problem occurs when the technique used to implement userdefined models in ADS is declaring 2 new components, 1 a modelform and another an instance. This implementation of user-defined models led to the requirement for *#echo* lines. The modelform component looked like any other ADS netlist component, but it had no nodes. The parser is modified for IC-CAP 2001 to recognize a nodeless component as a userdefined model; however, only in the context of a subcircuit. If you want to create *this* type of userdefined model in ADS, then you *must* use a subcircuit. Doing so eliminates the need for *#echo* lines in the netlist and the subcircuit will parse and simulate properly.

Non-Piped ADS Simulations

Non-piped ADS simulations are identical to non-piped MNS simulations. Execute a simulation with the Simulation Debugger ON to perform a non-piped simulation. ADS is capable of performing piped simulations, which enables you to turn the Simulation Debugger OFF without requiring that ADS be restarted for every simulation.

Circuit Model Description

This section explains the circuit descriptions for the ADS simulator.

Selecting Simulator Options

ADS simulation options are specified using the HPEESOFSIM_OPTIONS variable in the Setup DUT or System Variable tables. Enter the options in the value section of the variable exactly as they should appear in the ADS options command.

Entering Circuit Descriptions

The circuit description is entered into the IC-CAP Circuit Editor or the Test Circuit Editor. The circuit description includes the necessary definitions of devices, sources and components, as well as node connections and model descriptions. ADS accepts a netlist description that is different from SPICE and Saber simulators.

NOTE IC-CAP accepts a modified form of a netlist that enables you to use binning. To simulate a netlist with binned models from IC-CAP, you must declare the bin model (and only the bin model) immediately following the subcircuit definition. You must declare each *Model[x]=* to be a name of the form *XCKT.modname* since that is how IC-CAP netlists the bin model.

Parameter Table Generation

The circuit description is parsed by IC-CAP and specific model information (such as parameters and their corresponding values) as well as circuit component values are reflected in the Parameters table. Model parameters and component values specified in the circuit description entered in the Circuit Editor are saved in the Parameters table. Device parameters specified in the model call statement are saved in the DUT Parameters table—unless a Test Circuit is specified, in which case, parameter values specified in the test circuit description are saved in the DUT Parameters table.

By default, all parameter names will be converted to uppercase, since most extraction routines look for parameters named with all uppercase letters. Some extraction routines (e.g., *Root* models and *EExxx* models) require all lowercase letters. In these *.mdl* files, the variable HPEESOFSIM_USE_LOWER_CASE_PARAMS is declared to override the default behavior. If you want to write extraction routines using the native mixed case parameters, declare the variable HPEESOFSIM_USE_MIXED_CASE_PARAMS in your model file. For a description of these functions, see the System Variables.

Non-numeric Parameter Values

ADS allows non-numeric values for a number of parameters in predefined component definitions. One example is the BJT model parameter *npn*. This parameter can take on the value of *yes* if it is an nmos device. Alpha format parameters do not appear in the IC-CAP Parameters table but do appear in the simulation input decks.

Circuit descriptions must be entered with valid model and parameter names for the particular model being used.

Node Names

ADS accepts alphanumeric names as well as numbers to represent nodes. There is no limit on the number of characters allowed in a node name; however, delimiters or non-alphanumeric characters are not allowed. Also, a node name that begins with a digit must consist only of digits.

Numeric node names are discouraged as they will result in warnings during simulation that the results will not be displayed properly in ADS Data Display Server (DDS). However, these warnings are of no consequence to ICCap.

Comments

To indicate comments in an ADS input deck, start an input line with a semicolon (;). All text on the line following the semicolon will be ignored.

NOTE ADS will treat the suffix *M* as *MEG* and *m* as *milli*, whereas IC-CAP parses both *M* and *m* as *milli*. When specifying a value multiplied by10^{-3} use *m*; when specifying a value multiplied by 10^{6} use *MEG*.

Device Model Descriptions

A device model is used to characterize a single ADS-defined element of any type. This specification requires a model definition that describes the device and an instance statement that calls the model definition.

The model description specifies the value of a device model that describes a particular element. When a parameter is not specified, the default value in the model is used. The general form of the model definition is:

```
model MNAME TYPE PNAME1 = PVAL1 PNAME2 = PVAL2...
```

where

MNAME is the model name. (Regardless of the model name entered into the MNAME field of the ADS model definition statement, IC-CAP substitutes this field with the name of the Model as it is called in the Main window when the simulator input deck is built.)

TYPE is a valid ADS element type.

PNAMEs are parameter names available for the particular model type.

PVALs are the parameter values.

A backslash immediately followed by a return (no space between the backslash and the return) at the end of a line indicates that the statement is continued on the next line This continuation character is often used for easier readability when specifying the model description.

The general form of the instance statement that calls the device model is:

```
TYPE :DNAME NNAME1 NNAME2...NNAMEN DPAR1 = DVAL1
DPAR2 = DVAL2...DPARN = DVALN
```

where

TYPE is the instance type descriptor. This field can contain either the ADS instance type name or a user-supplied model or subcircuit name.

DNAME is the device name.

NNAMEs denote node names.

DPAR is a predefined DUT parameter name.

DVAL is the specified DUT parameter value. Refer to "General Syntax" on page 355 for DUT parameter names available for each model.

Subcircuit Model Descriptions

A subcircuit definition represents a circuit that contains more than 1 device. The syntax for defining a subcircuit is identical to the syntax used for the ADS input language.

The general form of the subcircuit definition is:

```
define SUBCKTNAME (NNAME1 NNAME2 ...NNAMEN)
parameters PAR1 = VAL1 PAR2 = VAL2 ...PARN = VALN
< body of subcircuit >
end SUBCKTNAME
```

where

SUBCKTNAME is the name of the subcircuit.

NNAMEs are the node names of the external nodes of the subcircuit. These external nodes are used to connect the subcircuit to another circuit.

*PAR*s are the names of the parameters passed into the subcircuit. These parameters are optional in a subcircuit definition.

If parameters are specified, the assigned default values *VAL* are also optional. A parameter is assigned to this default value if the parameter is not specified in the subcircuit call.

The body of the subcircuit contains element statements. It can contain calls to other subcircuits but it cannot contain other subcircuit definitions.

The subcircuit definition is completed using the *end* SUBCKTNAME statement.

Calling a subcircuit definition allows you to insert all instances specified within the subcircuit into the circuit. The call requires a syntax identical to the syntax used in the ADS input language for any instance statement. The general form of the instance statement is:

```
TYPE :INAME NNAME1 NNAME2....NNAMEN PAR1 = VAL1 PAR2 =
VAL2......PARN = VALN
```

(While the syntax shown here is correct, passed parameters are ignored by IC-CAP.)

where

TYPE is the instance type descriptor. If a subcircuit is being called, this field would contain the subcircuit name denoted by *SUBCKTNAME*.

INAME is the instantiated name of the subcircuit.

NNAMEs denote node names.

PARs are the subcircuit parameter names.

VALs are the specified subcircuit parameter values.

The following is an example of a complete subcircuit definition and subcircuit call.

- Added by IC-CAP for output format/etc.

```
Options ASCII_Rawfile=no UseNutmegFormat=yes
```

- Defined by the user in the Circuit folder:

```
;Simulation Input File in hpeesofsim Input Deck Format

global RC1_r=4352

define hpsimopamp (2 3 4 6 7 )
; Internal OpAmp circuit
; using Boyle-Pederson Macro Model
; Input differential amplifier
NPN1:Q1  10 2 12
NPN2:Q2  11 3 13
model NPN1 BJT NPN=yes  \
Is = 8E-16  \
Bf = 52.81
model NPN2 BJT NPN=yes  \
Is = 8.093E-16  \
Bf = 52.66
R:RC1  7 10 R=RC1_r
R:RC2  7 11 R=4352
C:C1  10 11 C=4.529E-12
R:RE1  12 14 R=2392
R:RE2  13 14 R=2392
R:RE  14 0 R=7.27E+06
C:CE  14 0 C=7.5E-12
; Power dissipation modeling resistor
R:RP  7 4 R=1.515E+04
; 1st gain stage
 #uselib "ckt", "VCCS"
VCCS:GCM  14 0 0 15 G=1.152E-09
VCCS:GA  10 11 15 0 G=0.0002298
R:R2  15 0 R=1E+05
; Compensation capacitor
C:C2  15 16 C=3E-11
; 2nd gain stage
VCCS:GB  15 0 16 0 G=37.1
R:RO2  16 0 R=489.2
DMOD1:D1  16 17
DMOD1:D2  17 16
model DMOD1 Diode  \
Is = 3.822E-32
R:RC  17 0 R=0.0001986
VCCS:GC  6 0 0 17 G=5034
; Output circuit
R:RO1  16 6 R=76.8
DMOD2:D3  6 18
DMOD2:D4  19 6
model DMOD2 Diode  \
Is = 3.822E-32
V_Source:VC  7 18 Vdc=1.604
V_Source:VE  19 4 Vdc=3.104
```

```
; Input diff amp bias source
I_Source:IEE  14 4 Idc=2.751E-05
end hpsimopamp
```

- Defined by the user in the Test Circuit folder:

```
; Inverting Amplifier
define inv_amp (1 2 3 4 6 7 )
hpsimopamp:X1  2 3 4 6 7
R:Rf  6 2 R=1E+04
R:Rin  2 1 R=2000
R:Rgnd  3 0 R=0.001
end inv_amp
```

- Added by IC-CAP to the circuit description:

```
inv_amp:XCKT n1 n2 n3 n4 n5 n6
; START SOURCES
V_Source:V1GROUND n1 0 Vdc=0 Vac=1
V_Source:V7GROUND n6 0 Vdc=15
V_Source:V4GROUND n4 0 Vdc=-15
; END SOURCES
R:RO2 n2 0 R=100MEG
R:RO3 n3 0 R=100MEG
R:RO5 n5 0 R=100MEG
SweepPlan:swpfreq  Start = 1000 Stop = 1e+07 Dec = 3
AC:ac1 SweepPlan=swpfreq SweepVar="freq"
```

ADS Parameter Sweeps

When using the ADS simulator in IC-CAP, the method of specifying parameter sweeps differs between performing single device simulations and circuit simulations.

NOTE When performing parameter sweeps, the name of the parameter to be swept must be recognized by ADS, since the analysis is performed from within the simulator. This means that the global declaration must be used within the ADS circuit description. Simply adding the parameter name to the Variables table results in a failed simulation.

Device Simulation Parameter Sweep

To sweep a parameter in an ADS device simulation:

1. Add an input specification of mode P to the Setup. Enter the name of the parameter as it appears in the Parameters table.
2. Enter the sweep type and values.

The Device Simulation Parameter Sweep example uses the *hpsimnpn.mdl* model with an input of mode P to the *fearly* setup. This input specifies a linear sweep of the parameter from 200.0e–15 to 230.0e–15 amperes in steps of 15.0e–15 amperes.

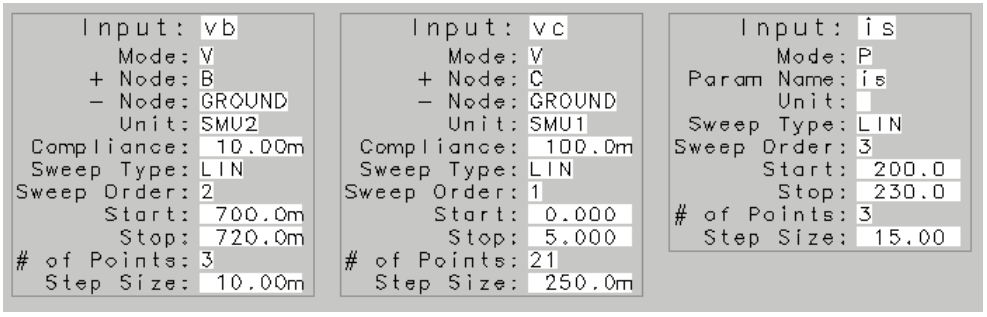


Figure 19 ADS Device Simulation Parameter Sweep Setup Example

During the simulation, IC-CAP generates the following input deck.

```
Options\
 ASCII_Rawfile=no UseNutmegFormat=yes
; Simulation Input File for BJT

model npn BJT NPN=yes  \
Is =  2.704E-16  \
Bf =  86.16  \
Nf =  0.979  \
Vaf =  86.95  \
Ikf =  0.01491  \
Ise =  1.886E-14  \
Ne =  1.522  \
Br =  8.799  \
Nr =  0.9967  \
Var =  9.757  \
Ikr =  0.02369  \
Isc =  1.095E-15  \
Nc =  1.1  \
Rb =  8.706  \
Irb =  0.001509  \
Rbm =  5.833  \
Re =  1.385  \
Rc =  10.68  \
Xtb =  0  \
Eg =  1.11  \
Xti =  3  \
Cje =  1.312E-12  \
Vje =  0.6151  \
Mje =  0.2052  \
Tf  =  4.781E-11  \
Xtf =  4.359  \
Vtf =  3.237  \
Itf =  0.01753  \
Ptf =  176.2  \
Cjc =  1.394E-12  \
Vjc =  0.5428  \
Mjc =  0.2254  \
Xcjc =  1  \
Tr  =  5.099E-09  \
Cjs =  1.004E-13  \
Vjs =  0.5668  \
Mjs =  0.2696  \
Fc =  0.5  \
Tnom =  27
npn:devckt 1 2 3 4
; START SOURCES
V_Source:VBGROUND 2 0 Vdc=0
V_Source:VCGROUND 1 0 Vdc=0
V_Source:VEGROUND 3 0 Vdc=0
V_Source:VSGROUND 4 0 Vdc=-3
; END SOURCES
SweepPlan:swp1 Start=0 Stop=5 Step=0.25
SweepPlan:swp2 Start=0.7 Stop=0.72 Step=0.01
DC:dc1 SweepPlan=swp1 SweepVar="VCGROUND.Vdc"
ParamSweep:ct1 SimInstanceName="dc1" SweepPlan=swp2
SweepVar="VBGROUND.Vdc"
```

Circuit Simulation Parameter Sweep

Specifying a parameter sweep for a circuit simulation requires a different approach from a parameter sweep for a device simulation.

To sweep a parameter in an ADS circuit simulation:

1. Specify a global variable in the ADS circuit description and set it to an initial value.
2. Set the value of the parameter in the circuit description equal to the global variable name.
3. Add a variable in IC-CAP with the same name as the global ADS parameter.
4. Add an input specification of mode P to the Setup.
5. Enter the global variable name in the Name field of the Input table.
6. Enter the sweep type and values.

Example Circuit Simulation Parameter Sweep

The Circuit Simulation Parameter Sweep example, uses a model for opamp simulation. The following line is included with the circuit description:

```
global RC1_r=4352
```

This complete circuit description is shown below.

```
;Simulation Input File in hpeesofsim Input Deck Format

global RC1_r=4352

define opamp1 (2 3 4 6 7)
; Internal OpAmp circuit
; using Boyle-Pederson Macro Model
; Input differential amplifier
NPN1:Q1 10 2 12
NPN2:Q2 11 3 13
model NPN1 BJT NPN=yes \
Is = 8E-16 \
Bf = 52.81
model NPN2 BJT NPN=yes \
Is = 8.093E-16 \
Bf = 52.66
R:RC1 7 10 R=RC1_r
R:RC2 7 11 R=4352
C:C1 10 11 C=4.529E-12
R:RE1 12 14 R=2392
```

```
R:RE2 13 14 R=2392
R:RE 14 0 R=7.27E+06
C:CE 14 0 C=7.5E-12
; Power dissipation modeling resistor
R:RP 7 4 R=1.515E+04
; 1st gain stage
#uselib "ckt", "VCCS"
VCCS:GCM 14 0 0 15 G=1.152E-09
VCCS:GA 10 11 15 0 G=0.0002298
R:R2 15 0 R=1E+05
; Compensation capacitor
C:C2 15 16 C=1E-11
; 2nd gain stage
VCCS:GB 15 0 16 0 G=37.1
R:RO2 16 0 R=489.2
DMOD1:D1 16 17
DMOD1:D2 17 16
model DMOD1 Diode \
Is = 3.822E-32
R:RC 17 0 R=0.0001986
VCCS:GC 6 0 0 17 G=5034
; Output circuit
R:RO1 16 6 R=76.8
DMOD2:D3 6 18
DMOD2:D4 19 6
model DMOD2 Diode \
Is = 3.822E-32
V_Source:VC 7 18 Vdc=1.604
V_Source:VE 19 4 Vdc=3.104
; Input diff amp bias source
I_Source:IEE 14 4 Idc=2.751E-05
end opamp1

define inv_amp (1 2 3 4 6 7 )
opamp1:X1  2 3 4 6 7
R:Rf  6 2 R=1E+004
R:Rin  2 1 R=2000
R:Rgnd  3 0 R=0.001
end inv_amp

inv_amp:XCKT n1 n2 n3 n4 n5 n6
; START SOURCES
V_Source:V1GROUND n1 0 Vdc=0 Vac=polar(1,0)
V_Source:V7GROUND n6 0 Vdc=15
V_Source:V4GROUND n4 0 Vdc=-15 ; END SOURCES
R:RO2 n2 0 R=100MEG
R:RO3 n3 0 R=100MEG
R:RO5 n5 0 R=100MEG
SweepPlan:swpfreq Start=1000 Stop=1e+07 Dec=3
SweepPlan:swp1 Start=4 Stop=10 Step=6
AC:ac1 SweepPlan=swpfreq SweepVar="freq"
ParamSweep:ct1 SimInstanceName="ac1"
SweepPlan=swp1 SweepVar="RC1_r"
```

In this example, the value of R:RC1 is set to *RC1_r*. You must also add a variable called RC1_r to the IC-CAP model variables table and set the variable to a value, such as, 4.000K. In the example model, you must then add an input call *RC1_r* to the setup . The Inputs table is shown in the following figure.

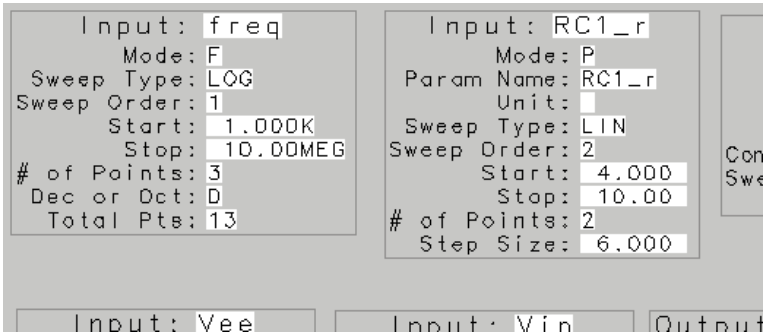


Figure 20 ADS Circuit Parameter Sweep Setup Example

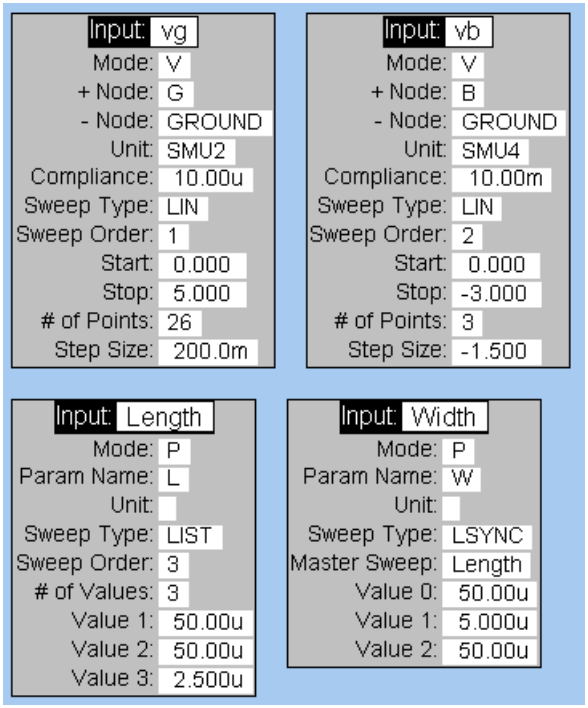
For additional information on sweeping parameters, refer to "Specifying Parameter or Variable Sweeps" in the *User's Guide*.

The following sections of this chapter describe in detail the syntax for the ADS Simulator.

Using LSYNC sweeps

When you use LSYNC sweeps for an ADS simulation, data is written to a data access component file. This file contains the synchronized lists and the specific elements in the netlist that refer to LSYNC values. These elements are accessed using variables and an index.

A single sweep for the LSYNC group is then created to sweep the index.



Example Netlist:

```
Options ASCII_Rawfile=no UseNutmegFormat=yes

model nmos3 MOSFET nmos=yes \
UO          = 1000       \
Vto         = 1.136      \
Nfs         = 0          \
Tox         = 1E-007     \
Nsub        = 5.31E+015  \
Nss         = 0          \
Vmax        = 1E+006     \
Rs          = 0          \
Rd          = 0          \
Rsh         = 0          \
Cbd         = 0          \
Cbs         = 0          \
Cj          = 0          \
Mj          = 0.5        \
Cjsw        = 0          \
Mjsw        = 0.33       \
Is          = 1E-014     \
Pb          = 0.8        \
Fc          = 0.5        \
Xj          = 9.438E-008 \
Ld          = 2.955E-007 \
Delta       = 0.9338     \
```

```
Theta       = 0.04124   \
Eta         = 0         \
Kappa       = 0.2

nmos3:devckt n1 n2 n3 n4 L = lsync0_0 W = lsync0_1 Ad = 1e-10
As = 1e-10 Pd = 0.000104 Ps = 0.000104 ; START SOURCES
V_Source:VGGROUND n2 0 Vdc=0 V_Source:VBGROUND n4 0 Vdc=0
V_Source:VDGROUND n1 0 Vdc=0.1 V_Source:VSGROUND n3 0 Vdc=0
; END SOURCES

INDEX0=0
#uselib "ckt" , "DAC"
DAC:DAC0 File="c:\ictmp\IC19_lsync0" Type="dscr"
InterpMode="index_lookup" iVar1=1 iVal1=INDEX0

lsync0_0=file {DAC0, "lval0"}
lsync0_1 = file {DAC0, "lval1"}
SweepPlan:swp1 Start=0 Stop=5 Step=0.2
SweepPlan:swp2 Start=-3 Stop=0 Step=1.5 Reverse=yes
SweepPlan:swp3 Start=0 Stop=2 Step=1
DC:dc1 SweepPlan=swp1 SweepVar="VGGROUND.Vdc"
ParamSweep:ct1 SimInstanceName="dc1" SweepPlan=swp2
SweepVar="VBGROUND.Vdc"
ParamSweep:ct2 SimInstanceName="ct1" SweepPlan=swp3
SweepVar="INDEX0"
```

And the contents of *IC19_lsync0* will be:

```
BEGIN DSCRDATA
% INDEX0 lval0 lval1
0 5e-05 5e-05
1 5e-05 5e-06
2 2.5e-06 5e-05
```

Interpreting this Chapter

To make this chapter more accurate and easier to update, much of the information in it is derived directly from the help facility in the ADS Simulator. The parameter information in the help facility has the following format.

```
Parameters:
    name (units)       attributes  description

Attributes:
    field 1: settable.
      s = settable.
      S = settable and required.
    field 2: modifiable.
      m = modifiable.
    field 3: optimizable.
      o = optimizable.
    field 4: readable.
      r = readable.
    field 5: type.
      b = boolean.
      i = integer.
      r = real number.
      c = complex number.
      d = device instance.
      s = character string.
```

Table 66 Model Parameter Attribute Definitions

Attribute	Meaning	Example
settable	Can be defined in the instance or model statement. Most parameters are settable, there are a few cases where a parameter is calculated internally and could be used either in an equation or sent to the dataset via the OutVar parameter on the simulation component. The parameter must have its full address.	Gbe (Small signal Base-Emitter Conductance) in the BJT model can be sent to the dataset by setting `OutVar="MySubCkt.X1.Gbe"` on the simulation component.
required	Has no default value; must be set to some value, otherwise the simulator will return an error.	
modifiable	The parameter value can be swept in simulation.	

Table 66 Model Parameter Attribute Definitions

Attribute	Meaning	Example
optimizable	The parameter value can be optimized.	
readable	Can be queried for value in simulation using the OutVar parameter. See settable.	
boolean	Valid values are 1, 0, True, and False.	
integer	The maximum value allowed for an integer type is 32767, values between 32767 and 2147483646 are still valid, but will be netlisted as real numbers. In some cases the value of a parameter is restricted to a certain number of legal values.	The Region parameter in the BJT model is defined as integer but the only valid values are 0, 1, 2, and 3.
real number	The maximum value allowed is 1.79769313486231e308+.	
complex number	The maximum value allowed for the real and imaginary parts is 1.79769313486231e308+.	
device instance	The parameter value must be set to the name of one of the instances present in the circuit.	The mutual inductance component (Mutual), where the parameters Inductor1 and Inductor2 are defined by instance names of inductors present in the circuit or by a variable pointing to the instance names. Inductor1="L1" or Inductor1=Xyz where Xyz="L1"
character string	Used typically for file names. Must be in double quotes.	Filename="MyFileName"

There are 2 other identifiers not in flag format. One is [ ] next to a parameter name and it means that the parameter is structured as an array. The other is (repeatable) appended to the parameter description and it means that the parameter can appear more than once in the same instance. An example is `OutVar`.

General Syntax

In this chapter, the following typographical conventions apply:

Table 67 Typographic Conventions

Type Style	Used For
[. . .]	Data or character fields enclosed in brackets are optional.
italics	Names and values in *italics* must be supplied
bold	Words in **bold** are ADS simulator keywords and are also required.

The ADS Simulator Syntax

The following sections outline the basic language rules.

Field Separators

A delimiter is one or more blanks or tabs.

Continuation Characters

A statement may be continued on the next line by ending the current line with a backslash and continuing on the next line.

Name Fields

A name may have any number of letters or digits in it but must not contain any delimiters or non alphanumeric characters. The name must begin with a letter or an underscore (_).

Table 68 Fundamental Units

Dimension	Fundamental Unit
Frequency	Hertz
Resistance	Ohms
Conductance	Siemens
Capacitance	Farads
Inductance	Henries
Length	meters
Time	seconds
Voltage	Volts
Current	Amperes
Power	Watts
Distance	meters
Temperature	Celsius

Parameter Fields

A parameter field takes the form *name* = *value*, where *name* is a parameter keyword and *value* is either a numeric expression, the name of a device instance, the name of a model or a character string surrounded by double quotes. Some parameters can be indexed, in which case the name is followed by *[i]*, *[i,j]*, or *[i,j,k]*. *i*, *j*, and *k* must be integer constants or variables.

Node Names

A node name may have any number of letters or digits in it but must not contain any delimiters or non alphanumeric characters. If a node name begins with a digit, then it must consist only of digits.

Lower / Upper Case

The ADS Simulator is case sensitive.

Units and Scale Factors

An integer or floating point number may be scaled by following it with either an e or E and an integer exponent (e.g., 2.65e3, 1e-14).

An ADS Simulator parameter with a given dimension assumes its value has the corresponding units. For example, for a resistance, R=10 is assumed to be 10 Ohms. The fundamental units for the ADS Simulator are shown in Table 68.

A number or expression can be scaled by following it with a scale factor. A scale factor is a single word that begins with a letter or an underscore. The remaining characters, if any, consist of letters, digits, and underscores. Note that ‘‘/’’ cannot be used to represent ‘‘per’’. The value of a scale factor is resolved using the following rule: If the scale factor exactly matches one of the predefined scale-factors (Table 69), then use the numerical equivalent; otherwise, if the first character of the scale factor is one of the legal scale-factor prefixes (Table 70), the corresponding scaling is applied.

Table 69 Predefined Scale Factors

Scale Factor	Scaling	Meaning
A	1	Amperes
F	1	Farads
ft	0.3048	feet
H	1	Henries
Hz	1	Hertz
in	0.0254	inches
meter	1	meters
meters	1	meters
metre	1	meters
metres	1	meters
mi	1609.344	miles
mil	$2.54*10^{-5}$	mils
mils	$2.54*10^{-5}$	mils
nmi	1852	nautical miles
Ohm	1	Ohms
Ohms	1	Ohms
S	1	Siemens
sec	1	seconds
V	1	Volts
W	1	Watts

Predefined Scale Factors

This type of scale factor is a predefined sequence of characters which the ADS Simulator parses as a single token. The predefined scale factors are listed in Table 69.

Single-character prefixes

If the first character of the scale factor is one of the legal scale-factor prefixes, the corresponding scaling is applied.The single-character prefixes are based on the metric system of scaling prefixes and are listed in Table 70

For example, `3.5 GHz` is equivalent to $3.5*10^{9}$ and `12 nF` is equivalent to $1.2*10^{-8}$. Note that most of the time, the ADS Simulator ignores any characters that follow the single-character prefix. The exceptions are noted in "Unrecognized Scale Factors" on page 360.

Most of these scale factors can be used without any additional characters (e.g., `3.5 G`, `12n`). This means that `m`, when used alone, stands for ''milli''.

The underscore _ is provided to turn off scaling. For example, `1e-9 _farad` is equivalent to 10^{-9}, and `1e-9` farad is equivalent to 10^{-24}.

Predefined scale factors are case sensitive.

Unless otherwise noted, additional characters can be appended to a predefined scale factor prefix without affecting its scaling value.

Table 70 Single-character prefixes

Prefix	Scaling	Meaning
T	10^{12}	tera
G	10^{9}	giga
M	10^{6}	mega
K	10^{3}	kilo
k	10^{3}	kilo
-	1	
m	10^{-3}	milli
u	10^{-6}	micro
n	10^{-9}	nano

Table 70 Single-character prefixes (continued)

Prefix	Scaling	Meaning
p	10^{-12}	pico
f	10^{-15}	femto
a	10^{-18}	atto

A predefined scale factor overrides any corresponding single-character-prefix scale factor. For example, 3 mm is equivalent to $3*10^{-3}$, not $3*10^{6}$. In particular, note that M does not stand for milli, m does not stand for mega, and F does not stand for femto.

There are no scale factors for dBm, dBW, or temperature, see section on "Functions" on page 372 for conversion functions.

Unrecognized Scale Factors

The ADS Simulator treats unrecognizable scale factors as equal to 1 and generates a warning message.

Scale-Factor Binding

More than one scale factor may appear in an expression, so expressions like `x in + y mil` are valid and behave properly.

Scale factors bind tightly to the preceding variable. For instance, `6 + 9 MHz` is equal to `9000006`. Use parentheses to extend the scope of a scale factor (e.g., `(6 + 9) MHz`).

Booleans

Many devices, models, and analyses have parameters that are boolean valued. Zero is used to represent false or no, whereas any number besides zero represents true or yes. The keywords **yes** and **no** can also be used.

Ground Nodes

Node 0 is assumed to be the ground node. Additional ground node aliases can be defined using the **ground** statement. Multiple **ground** statements can be used to define any number of ground aliases, but they must all occur at the top-level hierarchy in the netlist.

General Form:

Ground *[:name] node1 [... nodeN]*

Example:

```
Ground gnd
```

Global Nodes

Global nodes are user-defined nodes which exist throughout the hierarchy. The global nodes must be defined on the first lines in the netlist. They must be defined before they are used.

General Form:

globalnode *nodename1* [*nodename2*] [... *nodenameN*]

Example:

```
globalnode sumnode my_internal_node
```

Comments

Comments are introduced into an ADS Simulator file with a semicolon; they terminate at the end of the line. Any text on a line that follows a semicolon is ignored. Also, all blank lines are ignored.

Statement Order

Models can appear anywhere in the netlist. They do not have to be defined before a model instance is defined.

Some parameters expect a device instance name as the parameter value. In these cases, the device instance must already have been defined before it is referenced. If not, the device instance name can be entered as a quoted string using double quotes (").

Naming Conventions

The full name for an instance parameter is of the form:

[pathName].instanceName.parameterName[index]

where *pathName* is a hierarchical name of the form

[pathName].subcircuitInstanceName

The same naming convention is used to reference nodes, variables, expressions, functions, device terminals, and device ports.

For device terminals, the terminal name can be either the terminal name given in the device description, or *tn* where *n* is the terminal number (the first terminal in the description is terminal 1, etc.). Device ports are referenced by using the name *pm*, where *m* is the port number (the first pair of terminals in the device description is port 1, etc.).

Note that *t1* and *p1* both correspond to the current flowing into the first terminal of a device, and that *t2* corresponds to the current flowing into the second terminal. If terminals 1 and 2 define a port, then the current specified by *t2* is equal and opposite to the current specified by *t1* and *p1*.

Currents

The only currents that can be accessed for simulation, optimization, or output purposes are the state currents.

State currents

Most devices are voltage controlled, that is, their terminal currents can be calculated given their terminal voltages. Circuits that contain only voltage-controlled devices can be solved using node analysis. Some devices, however, such as

voltage sources, are not voltage controlled. Since the only unknowns in node analysis are the node voltages, circuits that contain non-voltage-controlled devices cannot be solved using node analysis. Instead, modified node analysis is used. In modified node analysis, the unknown vector is enlarged. It contains not only the node voltages but the branch currents of the non-voltage-controlled devices as well. The branch currents that appear in the vector of unknowns are called state currents. Since the ADS Simulator uses modified node analysis, the values of the state currents are available for output.

If the value of a particular current is desired but the current is not a state current, insert a short in series with the desired terminal. The short does not affect the behavior of the circuit but does create a state current corresponding to the desired current.

To reference a state current, use the device instance name followed by either a terminal or port name. If the terminal or port name is not specified, the state current defaults to the first state current of the specified device. Note that this does not correspond to the current through the first port of the device whenever the current through the first port is not a state current. For some applications, the positive state current must be referenced, so a terminal name of *t1* or *t3* is acceptable but not *t2*. Using port names avoids this problem. The convention for current polarity is that positive current flows into the positive terminal.

Instance Statements

General Form:

type [:name] node1 ... nodeN [[param=value] ...]

type [:name] [[param=value] ...]

Examples:

```
ua741:OpAmp in out out
C:C1 2 3 C=10pf
HB:Distortion1 Freq=10GHz
```

The instance statement is used to define to the ADS Simulator the information unique to a particular instance of a device or an analysis. The instance statement consists of the instance type descriptor and an optional name preceded by a colon. If it is a device instance with terminals, the nodes to which the terminals of the instance are connected come next. Then the parameter fields for the instance are defined. The parameters can be in any order. The nodes, though, must appear in the same order as in the device or subcircuit definition.

The type field may contain either the ADS Simulator instance type name, or a user-supplied model or subcircuit name. The name can be any valid name, which means it must begin with a letter, can contain any number of letters and digits, must not contain any delimiters or non alphanumeric characters, and must not conflict with other names including node names.

Model Statements

General Form:

model *name type* [[*param* = *value*] ...]

Examples:

```
model NPNbjt bjt NPN=yes Bf=100 Js=0.1fa
```

Often characteristics of a particular type of element are common to a large number of instances. For example, the saturation current of a diode is a function of the process used to construct the diode and also of the area of the diode. Rather than describing the process on each diode instantiation, that description is done once in a model statement and many diode instances refer to it. The area, which may be different for each device, is included on each instance statement. Though it is possible to have several model statements for a particular type of device, each instance may only reference at most one model. Not all device types support model statements.

The name in the *model* statement becomes the type in the *instance* statement. The type field is the ADS Simulator-defined model name. Any parameter value not supplied will be set to the model's default value.

Most models, such as the diode or bjt models, can be instantiated with an instance statement. There are exceptions. For instance, the *Substrate* model cannot be instantiated. Its name, though, can be used as a parameter value for the *Subst* parameter of certain transmission line devices.

Subcircuit Definitions

General Form:

```
define subcircuitName ( node1 ... nodeN )
   [ parameters name1 = [ value1 ] ... name n = [ value n ] ]
                          .
                          .
                          .
             elementStatements
                          .
                          .
                          .
end [ subcircuitName ]
```

Examples:

```
define DoubleTuner (top bottom left right)
parameters vel=0.95 r=1.0 l1=.25 l2=.25
    tline:tuner1 top bottom left left len=l1 vel=vel r=r
    tline:tuner2 top bottom right right len=l2 vel=2*vel r=r
end DoubleTuner
DoubleTuner:InputTuner t1 b2 3 4 l1=0.5
```

A subcircuit is a named collection of instances connected in a particular way that can be instantiated as a group any number of times by subcircuit calls. The subcircuit call is in effect and form, an instance statement. Subcircuit definitions are simply circuit macros that can be expanded anywhere in the circuit any number of times. When an instance in the input file refers to a subcircuit definition, the instances specified within the subcircuit are inserted into the circuit. Subcircuits may be nested. Thus a subcircuit definition may contain other subcircuits. However, a subcircuit definition cannot contain another subcircuit definition. All the definitions must occur at the top level.

An instance statement that instantiates a subcircuit definition is referred to as a subcircuit call. The node names (or numbers) specified in the subcircuit call are substituted, in order, for the node names given in the subcircuit definition. All instances that refer to a subcircuit definition must have the same number of nodes as are specified in the subcircuit definition and in the same order. Node names inside the subcircuit definition are strictly local unless they are a global ground defined with a ground statement or global nodes defined with a **globalnode** statement. A subcircuit definition with no nodes must still include the parentheses ( ).

Parameter specification in subcircuit definitions is optional. Any parameters that are specified are referred to by name followed by an equals sign and then an optional default value. If, when making a subcircuit call in your input file, you do not specify a particular parameter, then this default value is used in that instance. Subcircuit parameters can be used in expressions within the subcircuit just as any other variable.

Subcircuits are a flexible and powerful way of developing and maintaining hierarchical circuits. Parameters can be used to modify one instance of a subcircuit from another. Names within a subcircuit can be assigned without worrying about conflicting with the same name in another subcircuit definition. The full name for a node or instance include its path name in addition to its instance name. For example, if the above subcircuit is included in `subckt2` which is itself included in `subckt1`, then the full path name of the length of the first transmission line is `subckt1.subckt2.tuner1.len`.

Only enough of the path name has to be specified to unambiguously identify the parameter. For example, an analysis inside `subckt1` can reference the length by `subckt2.tuner1.len` since the name search starts from the current level in the hierarchy. If a reference to a name cannot be resolved in the local level of hierarchy, then the parent is searched for the name, and so on until the top level is searched. In this way, a sibling can either inherit its parent's attributes or define its own.

Expression Capability

The ADS Simulator has a powerful and flexible symbolic expression capability, called *VarEqn*, which allows the user to define variables, expressions, and functions in the netlist. These can then be used to define other *VarEqn* expressions and functions, to specify device parameters and optimization goals, etc.

The names for *VarEqn* variables, expressions, and functions follow the same hierarchy rules that instance and node names do. Thus, local variables in a subcircuit definition can assume values that differ from one instance of the subcircuit to the next.

Functions and expressions can be defined either globally or locally anywhere in the hierarchy. All variables are local by default. Local variables are known in the subcircuit in which they are defined, and all lower subcircuits; they are not known at higher levels. Expressions defined at the root (the top level) are known everywhere within the circuit. To specify an expression to be global the **global** keyword must precede the expression. The **global** keyword causes the variable to be defined at the root of the hierarchy tree regardless of the lexical location.

Examples:

```
global exp1 = 2.718
```

The expression capability includes the standard math operations of + - / * ^ in addition to parenthesis grouping. Scale factors are also allowed in general expressions and have higher precedence than any of the math operators (see "Units and Scale Factors" on page 357).

Constants

An integer constant is represented by a sequence of digits optionally preceded by a negative sign (e.g, `14`, `-3`).

A real number contains a decimal point and/or an exponential suffix using the `e` notation (e.g, `14.0`, `-13e-10`).

The only complex constant is the predefined constant `j` which is equal to the square root of -1. It can be used to generate complex constants from real and integer constants (e.g., `j*3`, `9.1 + j*1.2e-2`). The predefined functions `complex()` and `polar()` can also be used to enter complex constants into an expression.

A string constant is delimited by single quotes (e.g.,`'string','this is a string'`).

Predefined Constants

Table 71 Predefined Constants

Constant	Definition	Constant	Definition
boltzmann	Boltzmann's constant	ln10	2.30...
c0	Speed of light in a vacuum	j	Square root of -1
DF_DefaultInt	Reference to default int value defined in Data Flow controller	pi	3.14...
DF_ZERO_OHMS	Symbol for use as zero ohms	planck	Planck's constant
e	2.718...	qelectron	Charge of an electron
e0	Permittivity of a vacuum	tinyReal	Smallest real number
hugeReal	Largest real number	u0	Permeability of a vacuum

Variables

General Form:

variableName = *constantExpression*

Examples:

```
x1 = 4.3inches + 3mils
syc_a = cos(1.0+sin(pi*3))
Zin = 7.8k - j*3.2k
```

The type of a variable is determined by the type of its value. For example, `x=1` is an integer, `x=1+j` is complex, and `x = "tuesday"` is a string.

Predefined Variables

In addition to the predefined constants, there are several predefined global variables. Since they are variables, they can be modified and swept.

__fdd	Flag to indicate a new FDD instance	
__fdd_v	Flag to indicate updated FDD state vars	
_ac_state	Is analyses in AC state	
_c1 to _c30	Symbolic controlling current	
_dc_state	Is analyses in DC state	
_freq1 to _freq12	Fundamental frequency	
_harm	Harmonic number index for sources and FDD	
_hb_state	Is analyses in harmonic balance state	
_p2dInputPower	Port input power for P2D simulation	
_sigproc_state	Is analyses in signal processing state	
_sm_state	Is analyses in sm state	
_sp_state	Is analyses in sparameter analysis state	
_tr_state	Is analyses in transient state	
CostIndex	Index for optimization cost plots	
DF_Value	Reference to corresponding value defined in Data Flow controller	
DefaultValue	Signal processing default parameter value	
DeviceIndex	Device Index used for noise contribution or DC OP output	
dcSourceLevel	used for DC source-level sweeping	
doeindex	Index for Design of Experiment sweeps	
freq	The frequency in Hertz of the present simulation	(1MHz)
logNodesetScale	Used for DC nodeset simulation	
logRshunt	Used for DC Rshunt sweeping	

mcTrial	Trial counter for Monte Carlo based simulations
noisefreq	The spectral noise analysis frequency
Nsample	Signal processing analysis sample number
optIter	Optimization job iteration counter
temp	The ambient temperature, in degrees Celsius. (25 degrees)
time	The analysis time
timestep	The analysis time step
tranorder	The transient analysis integration order
ScheduleCycle	Signal processing schedule cycle number
sourcelevel	The relative attenuation of the spectral sources (1.0)
ssfreq	The small-signal mixer analysis frequency
_v1 to _v19	State variable voltages used by the sdd device
_i1 to _i19	State variable currents used by the sdd device
mc_index	Index variable used by Monte Carlo controller

The `sourcelevel` variable is used by the spectral analysis when it needs to gradually increase source power from 0 to full scale to obtain convergence. It can be used by the user to sweep the level of ALL spectral source components, but is not recommended. The `_v` and `_i` variables should only be used in the context of the sdd device.

Expressions

General Form:

expressionName = *nonconstantExpression*

Examples:

```
x1 = 4.3 + freq;
syc_a = cos(1.0+sin(pi*3 + 2.0*x1))
Zin = 7.8 ohm + j*freq * 1.9 ph
y = if (x equals 0) then 1.0e100 else 1/x endif
```

The main difference between expressions and variables is that a variable can be directly swept and modified by an analysis but an expression cannot. Note however, that any instance

parameter that depends on an expression is updated whenever one of the variables that the expression depends upon is changed (e.g., by a sweep).

Predefined Expressions

gaussian =	_gaussian_tol(10.0)	default gaussian distribution
nfmin =	_nfmin()	the minimum noise figure
omega =	2.0*pi*freq	the analysis frequency
rn =	_rn()	the noise resistance
sopt =	_sopt	the optimum noise match
tempkelvin =	temp + 273.15	the analysis temperature
uniform =	_uniform_tol(10.0)	default uniform distribution

Functions

General Form:

functionName(*[arg1, ..., argn]*) = *expression*

Examples:

```
y_srl(freq, r, l) = 1.0/(r + j*freq*l)
expl(a,b) = exp(a)*step(b-a) + exp(b)*(a-b-1)*step(a-b)
```

In *expression*, the function's arguments can be used, as can any other *VarEqn* variables, expressions, or functions.

Predefined Functions

_discrete_density(...)	user-defined discrete density function
_gaussian([*mean*, *sigma*, *lower_n_sigmas*, *upper_n_sigmas*, *lower_n_sigmas_del*, *upper_n_sigmas_del*])	gaussian density function

_gaussian_tol[*percent_tol, lower_n_sigmas, upper_n_sigmas, lower_percent_tol, upper_percent_tol, lower_n_sigmas_del, upper_n_sigmas_del*])	gaussian density function (tolerance version)
_get_fnom_freq(...)	Get analysis frequency for FDD carrier frequency index and harmonic
_lfsr(*x, y, z*)	linear feedback shift register (trigger, seed, taps)
_mvgaussian(...)	multivariate gaussian density function (correlation version)
_mvgaussian_cov(...)	multivariate gaussian density function (covariance version)
_n_state(*x, y*)	_n_state(*arr, val*) array index nearest value
_pwl_density(...)	user-defined piecewise-linear density function
_pwl_distribution(...)	user-defined piecewise-linear distribution function
_randvar(*distribution, mcindex, [nominal, tol_percent, x_min, x_max, lower_tol, upper_tol, delta_tol, tol_factor*])	random variable function
_shift_reg(*x, y, z, t*)	(trigger, mode(ParIn:MSB1st), length, input)
_uniform([*lower_bound, upper_bound*])	uniform density function
_uniform_tol([*percent_tol, lower_tol, upper_tol*])	uniform density function (tolerance version)
abs(*x*)	absolute value function
access_all_data(...)	datafile indep+dep lookup/interpolation function
access_data(...)	datafile dependents' lookup/interpolation function
arcsinh(*x*)	arcsinh function
arctan(*x*)	arctan function
atan2(*y, x*)	arctangent function (2 real arguments)
awg_dia(*x*)	wire gauge to diameter in meters
bin(*x*)	function convert a binary to integer

bitseq(*time*, [*clockfreq*, *trise*, *tfall*, *vlow*, *vhigh*, *bitseq*])	bitsequence function
complex(*x*, *y*)	real-to-complex conversion function
conj(*x*)	complex-conjugate function
cos(*x*)	cosine function
cos_pulse(*time*, [*low*, *high*, *delay*, *rise*, *fall*, *width*, *period*])	periodic cosine shaped pulse function
cosh(*x*)	hyperbolic cosine function
cot(*x*)	cotangent function
coth(*x*)	hyperbolic cotangent function
ctof(*x*)	convert Celsius to Fahrenheit
ctok(*x*)	convert Celsius to Kelvin
cxform(*x*, *y*, *z*)	transform complex data
damped_sin(*time*, [*offset*, *amplitude*, *freq*, *delay*, *damping*, *phase*])	damped sin function
db(*x*)	decibel function
dbm(*x*, *y*)	convert voltage and impedance into dbm
dbmtoa(*x*, *y*)	convert dbm and impedance into short circuit current
dbmtov(*x*, *y*)	convert dbm and impedance into open circuit voltage
dbmtow(*x*)	convert dBm to Watts
dbpolar(*x*, *y*)	(dB,angle)-to-rectangular conversion function
dbwtow(*x*)	convert dBW to Watts
deembed(*x*)	deembedding function
deg(*x*)	radian-to-degree conversion function
dep_data(*x*, *y*, [*z*])	dependent variable value
dphase(*x*, *y*)	Continuous phase difference (radians) between x and y
dsexpr(*x*, *y*)	Evaluate a dataset expression to an hpvar
dstoarray(*x*, [*y*])	Convert an hpvar to an array
echo(*x*)	echo-arguments function

erf_pulse(*time*, [*low*, *high*, *delay*, *rise*, *fall*, *width*, *period*])	periodic error function shaped pulse function
eval_poly(*x, y, z*)	polynomial evaluation function
exp(*x*)	exponential function
exp_pulse(*time, [low, high, delay1, tau1, delay2, tau2*])	exponential pulse function
fread(*x*)	raw-file reading function
ftoc(*x*)	convert Fahrenheit to Celsius
ftok(*x*)	convert Fahrenheit to Kelvin
get_array_size(*x*)	Get the size of the array
get_attribute(...)	value of attribute of a set of data
get_block(*x*, *y*)	HPvar tree from block name function
get_fund_freq(*x*)	Get the frequency associated with a specified fundamental index
get_max_points(*x*, *y*)	maximum points of independent variable
imag(*x*)	imaginary-part function
index(*x*, *y*, [z, *t*])	get index of name in array
innerprod(...)	inner-product function
int(*x*)	convert-to-integer function
itob(*x*, [*y*])	convert integer to binary
jn(*x*, *y*)	bessel function
ktoc(*x*)	convert Kelvin to Celsius
ktof(*x*)	convert Kelvin to Fahrenheit
length(*x*)	returns number of elements in array
limit_warn([*x, y, z, t, u*])	limit, default and warn function
list(...)	
ln(*x*)	natural log function
log(*x*)	log base 10 function
mag(*x*)	magnitude function
makearray(...)	(1:real-2:complex-3:string, y, z..) or (array, startIndex, stopIndex)
max(*x*, *y*)	maximum function

min(*x, y*)	minimum function
multi_freq(*time, amplitude, freq1, freq2, n*, [*seed*])	multifrequency function
names(*x*, *y*)	array of names of indepVars and/or depVars in dataset
norm(*x*)	norm function
phase(*x*)	phase (in degrees) function
phase_noise_pwl(...)	piecewise-linear function for computing phase noise
phasedeg(*x*)	phase (in degrees) function
phaserad(*x*)	phase (in radians) function
polar(*x*, *y*)	polar-to-rectangular conversion function
polarcpx(...)	polar to rectangular conversion function
pulse(*time, [low, high, delay, rise, fall, width,* period])	periodic pulse function
pwl(...)	piecewise-linear function
pwlr(...)	piecewise-linear-repeated function
rad(*x*)	degree-to-radian conversion function
ramp(*x*)	ramp function
read_data(...)	read_data("file-dataset", "locName", "fileType")
read_lib(...)	read_lib("libName", "item", "fileType")
real(*x*)	real-part function
rect(*x*, *y*, *z*)	rectangular pulse function
rem(...)	remainder function
ripple(*x, y, z, v*)	ripple(amplitude, intercept, period, variable) sinusoidal ripple function
rms(...)	root-mean-square function
rpsmooth(*x*)	rectangular-to-polar smoothing function
scalearray(*x, y*)	scalar times a vector (array) function
setDT(*x*)	Turns on discrete time transient mode (returns argument)

sffm(*time, [offset, amplitude, carrier_freq, mod_index, signal_freq*])	signal frequency FM
sgn(*x*)	signum function
sin(*x*)	sine function
sinc(*x*)	sin(x)/x function
sinh(*x*)	hyperbolic sine function
sprintf(*x*, *y*)	formatted print utility
sqrt(*x*)	square root function
step(*x*)	step function
tan(*x*)	tangent function
tanh(*x*)	hyperbolic tangent function
vswrpolar(*x*, *y*)	(VSWR,angle)-to-rectangular conversion function

NOTE The VarEqn trigonometric functions always expect the argument to be specified in radians. If the user wants to specify the angle in degrees then the VarEqn function deg() can be used to convert radians to degrees or the VarEqn function rad() can be used to convert degrees to radians.

Detailed Descriptions of the Predefined Functions

`_discrete_density` (x_1, p_1, x_2, p_2, ...) allows the user to define a discrete density distribution: returns x_1 with probability p_1, x_2 with probability p_2, etc. The x_n, p_n pairs needn't be sorted. The p_ns will be normalized automatically.

`_gaussian( [`*mean*, *sigma*, *lower_n_sigmas*, *upper_n_sigmas*, *lower_n_sigmas_del*, *upper_n_sigmas_del*]) returns a value randomly distributed according to the standard bell-shaped curve. *mean* defaults to 0. *sigma* defaults to 1. *lower_n_sigmas*, *upper_n_sigmas* define truncation limits (default to 3). *lower_n_sigmas_del* and *upper_n_sigmas_del* define a range in which the probability is zero (a bimodal distribution). `_gaussian_tol( [`*percent_tol*, *lower_n_sigmas*, *upper_n_sigmas*, *lower_percent_tol*, *upper_percent_tol*, *lower_n_sigmas_del*, *upper_n_sigmas_del*]

) is similar, but *percent_tol* defines the percentage tolerance about the nominal value (which comes from the RANDVAR expression).

`_get_fnom_freq(`x) returns the actual analysis frequency associated with the carrier frequency specified in the surrounding FDD context. If x is negative, it is the carrier frequency index. If x is positive, it is the harmonic index.

`_mvgaussian`(N, $mean_1$, ... $mean_N$, $sigma_1$, ... $sigma_N$, $correlation_{1,2}$, ..., $correlation_{1,N}$, ..., $correlation_{N\text{-}1,N}$) multivariate gaussian density function (correlation version). Returns an N dimensional vector. The correlation coefficient matrix must be positive definite. _mvgaussian_cov(N, $mean_1$, ... $mean_N$, $sigma_1$, ... $sigma_N$, $covariance_{1,2}$, ..., $covariance_{1,N}$, ..., $covariance_{N\text{-}1,N}$) is similar, but defined in terms of covariance. The covariance matrix must be positive definite.

`_pwl_density`(x_1, p_1, x_2, p_2, ...) returns a value randomly distributed according to the piecewise-linear density function with values p_n at x_n, i.e. it will return x_n with probability p_n and return

$$x_n + \varepsilon \text{ with probability } p_n + \varepsilon\frac{p_{n+1} - p_n}{x_{n+1} - x_n}$$

The x_n, p_n pairs needn't be sorted. The p_ns will be normalized automatically. _pwl_distribution(x_1, p_1, x_2, p_2, ...) is similar, but is defined in terms of the distribution values. It will return a value less than or equal to x_n with probability p_n. The x_n, p_n pairs will be sorted in increasing x_n order. After sorting, the p_ns should never decrease. The p_ns will be normalized so that p_N=1.

`_randvar`(*distribution*, *mcindex*, [*nominal, tol_percent*, *x_min*, *x_max*, *lower_tol*, *upper_tol*, *delta_tol*, *tol_factor*]) returns a value randomly distributed according to the *distribution*. The value will be the same for a given value of *mcindex*. The other parameters are interpreted according to the *distribution*.

_shift_reg(x, y, z, t) implements a z-bit shift register. x specifies the trigger. y = 0 means LSB First, Serial To Parallel, 1 means MSB First, Serial To Parallel, 2 means LSB First, Parallel to Serial, 3 means MSB First, Parallel to Serial. t is the input (output) value.

_uniform([*lower_bound*, *upper_bound*]) returns a value between *lower_bound* and *upper_bound*. All such values are equally probable. _uniform_tol([*percent_tol*, *lower_tol*, *upper_tol*]) is similar, but tolerance version.

access_all_data(*InterpMode*, *source*, $indep_1$, dep_1 ...) datafile independent and dependent lookup/interpolation function.

access_data(*InterpMode*, *nData*, *source*, dep_1 ...) datafile dependents' lookup/interpolation function.

bin(*String*) calculates the integer value of a sequence of 1's and 0's. For example bin('11001100') = 204. The argument of the bin function must be a string denoted by single quotes. The main use of the bin function is with the *System Model Library* to define an integer which corresponds to a digital word.

cxform(x, *OutFormat*, *InFormat*) transform complex data x from format *InFormat* to format *OutFormat*. The values for *OutFormat* and *InFormat* are 0: real and imaginary, 1: magnitude (linear) and phase (degrees), 2: magnitude (linear) and phase (radians), 3: magnitude (dB) and phase (degrees), 4: magnitude (dB) and phase (radians), 5: magnitude (SWR) and phase (degrees), 6: magnitude (SWR) and phase (radians). For example, to convert linear magnitude and phase in degrees to real and imaginary parts:

```
result = cxform(invar, 0, 1)
```

damped_sin(*time*, [*offset*, *amplitude*, *freq*, *delay*, *damping*, *phase*]). See "Transient Source Functions" on page 384.

The function db(x) is a shorthand form for the expression: 20log(mag(x)).

The deembed(x) function takes an array, x, of 4 complex numbers (the 2-port S-parameter array returned from the *VarEqn* interp() function) and returns an array of equivalent

de-embedding S-parameters for that network. The array must be of length 4 (2 x 2--two-port data only), or an error message will result. The transformation used is:

$$S_{11}^{-1} = \frac{S_{11}}{det}$$

$$S_{21}^{-1} = \frac{S_{21}}{det}$$

$$S_{12}^{-1} = \frac{S_{12}}{det}$$

$$S_{22}^{-1} = \frac{S_{22}}{det}$$

where *det* is the determinant of the 2 x 2 array.

CAUTION This transformation assumes that the S-parameters are derived from equal port termination impedances. *This transformation does not work when the port impedances are unequal.*

The function `deg`(x) converts from radians to degrees.

`dphase`(x, y) Calculates phase difference phase(x)-phase(y) (in radians).

`dsexpr`(x, y) Evaluate x, a DDS expression, to an hpvar. y is the default location data directory.

`echo`(x) prints argument on terminal and returns it as a value.

`erf_pulse`(*time*, [*low*, *high*, *delay*, *rise*, *fall*, *width*, *period*]) periodic pulse function, edges are error function (integral of Gaussian) shaped.

`eval_poly`(*x*, *y*, *z*) y is a real number. z is an integer that describes what to evaluate: -1 means the integral of the polynomial, 0 means the polynomial itself, +1 means the derivative of the polynomial. x is a *VarEqn* array that contains real numbers. The polynomial is $x_0 + x_1 y + x_2 y^2 + x_3 y^3 \ldots$

`exp_pulse`(*time*, [*low*, *high*, *delay1*, *tau1*, *delay2*, *tau2*]) See "Transient Source Functions" on page 384.

`get_fund_freq`(*fund*) returns the value of frequency (in Hertz) of a given fundamental defined by *fund*.

`index`(*nameArray*, "varName", [*caseSense*, *length*]) returns position of "varName" in *nameArray*, -1 if not found. *caseSense* sets case-sensitivity, defaults to yes. *length* sets how many characters to check, defaults to 0 (all).

`innerprod`(*x*, *y*) forms the inner product of the vectors *x* and *y*:

$$innerprod(x, y) = \sum_{i=0}^{n} x_i^* y_i$$

j and *k* are optional integers which specify a range of harmonics to include in the calculation:

$$innerprod(x, y, j, k) = \sum_{i=j}^{k} x_i^* y_i$$

j defaults to 0 and *k* defaults to infinity.

`int`(*x*) Truncates the fractional part of *x*.

`itob`(*x*, [*bits*]) convert integer *x* to *bits*-*bit* binary string.

The function `jn`(*n*, *x*) is the *n*-th order bessel function evaluated at *x*.

`limit_warn`([*Value*, *Min*, *Max*, *default*, *Name*]) sets *Value* to *default*, if not set. Limits it to *Min* and *Max* and generates a warning if the value is limited.

`makearray`(*arg1*[,*arg2*,..] creates an array with elements defined by *arg1* to *argN* where N can be any number of arguments. The data type of *args* must be Integer, Real, or Complex and the same for all *args*.

```
word = bin('1101')
fibo = makearray(0,1,1,2,3,5,8,word)
foo = fibo[0]
```

`multi_freq`(*time*, *amplitude*, *freq1*, *freq2*, *n*, [*seed*]) *seed* defaults to 1. If it is 0, phase is set to 0, otherwise it is used as a seed for a randomly-generated phase.

`norm`(x) returns the L-2 norm of the spectrum x:

$$norm(x) = \sqrt{innerprod(x, x)}$$

j and k are optional integers which specify a range of harmonics to include in the calculation:

$$norm(x, j, k) = \sqrt{innerprod(x, x, j, k)}$$

j defaults to 0 and k defaults to infinity.

`phase`(x) is the same as phasedeg(x).

The function `phasedeg`(x) returns phase in degrees.

The function `phaserad`(x) returns phase in radians.

The function `polarcpx`(x[,*leave_as_real*]) takes a complex argument, assumes that the real and complex part of the argument represents *mag* and *phase* (in radians) information, and converts it to real/imaginary. If the argument is real or integer instead of complex, the imaginary part is assumed to be zero. However, if the optional *leave_as_real* variable is specified, and is the value ‘‘1’’ (note that the legal values are ‘‘0’’ and ‘‘1’’ only), a real argument will be not be converted to a complex one.

`pulse`(*time*, [*low*, *high*, *delay*, *rise*, *fall*, *width*, *period*]) See “Transient Source Functions” on page 384.

`pwl`(...) piecewise-linear function. See “Transient Source Functions” on page 384.

`pwlr`(...) piecewise-linear-repeated function.

The function `rect`(t, tc, tp) is pulse function of variable t centered at time tc with duration tp.

The function `rad`(x) converts from degrees to radians.

ramp(x) 0 for $x < 0$, x for $x \geq 0$

`read_data`(*source*, *locName*, [*fileType*]) returns data from a file or dataset. *source* = “file” --- “dataset”. *locName* is the name of the source. *fileType* specifies the file type.

`read_lib`(*libName*, *locName*, [*fileType*]) returns data from a library. *libName* is the name of the library. *locName* is the name of the source. *fileType* specifies the file type.
read_lib("libName", "item", "fileType")

`rect`(x, y, z) Returns:

z	$\lvert x - y \rvert < \lvert z \rvert$	$\lvert x - y \rvert > \lvert z \rvert$
> 0	1	0
< 0	0	1

`rem`(x, [y]) Returns remainder of dividing x/y. y defaults to 0 (which returns x).

`rms`(x) returns the RMS value (including DC) of the spectrum x:

$$rms(x) = \frac{norm(x)}{\sqrt{2.0}}$$

j and k are optional integers which specify a range of harmonics to include in the calculation:

$$rms(x, j, k) = \frac{norm(x, j, k)}{\sqrt{2.0}}$$

j defaults to 0 and k defaults to infinity.

The function `rpsmooth`(x) takes a *VarEqn* pointer (one returned by readraw()), converts to polar format the rectangular data given by the *VarEqn* pointer, and smooths out ‘phase discontinuities’.

CAUTION

This function uses an algorithm that assumes that the first point is correct (i.e., not off by some multiple of 2π) and that the change in phase between any 2 adjacent points is less than π. This interpolation will not work well with noisy data or with data within roundoff error of zero. It should be used only with S-parameters in preparation for interpolation or extrapolation by one of the interpolation functions like interp1(). Also note that the result is left in a polar 'mag/phase' format stored in a complex number; the real part is magnitude, and the imaginary part is phase. The polarcpx() function must be used to convert the result of the rpsmooth() function back into a real/imaginary format.

sffm(*time*, [*offset*, *amplitude*, *carrier_freq*, *mod_index*, *signal_freq*]) See "Transient Source Functions" on page 384.

The `sprintf()` function is similar to the `C` function which takes a format string for argument *s* and a print argument *x* (*x* must be a string, an integer, or a real number) and returns a formatted string. This string then may be written to the console using the `system` function with an `echo` command.

Transient Source Functions

There are several built-in functions that mimic Spice transient sources. They are:

SPICE source	ADS Simulator function
exponential	exp_pulse(*time*, *low*, *high*, *tdelay1*, *tau1*, *tdelay2*, *tau2*)
single-frequency FM	sffm(*time*, *offset*, *amplitude*, *carrier_freq*, *mod_index*, *signal_freq*)
damped sine	damped_sin(*time*, *offset*, *amplitude*, *freq*, *delay*, *damping*)
pulse	pulse(*time*, *low*, *high*, *delay*, *rise*, *fall*, *width*, *period*)
piecewise linear	pwl(*time*, *t1*, *x1*, ..., *tn*, *xn*)

There functions are typically used with the *vt* parameter of the voltage source and the *it* parameter of the current source.

exp_pulse

Examples:

```
ivs:vin n1 0 vt=exp_pulse(time)
ics:iin n1 0 it=exp_pulse(time, -0.5mA, 0.5mA, 10ns, 5ns,
20ns, 8ns)
```

Arguments for exp_pulse

Name	Optional	Default
TIME	NO	
LOW	YES	0
HIGH	YES	1
TDELAY1	YES	0
TAU1	YES	TSTEP
TDELAY2	YES	TDELAY1 + TSTEP
TAU2	YES	TSTEP

TSTEP is the output step-time time specified on the TRAN analysis.

sffm

Examples:

```
ivs:vin n1 0 vt=sffm(time, , , , 0.5)
ics:iin n1 0 it=sffm(time, 0, 2, 1GHz, 1.2, 99MHz)
```

Arguments for sffm

Name	Optional	Default
TIME	NO	
OFFSET	YES	0
AMPLITUDE	YES	1
CARRIER_FREQ	YES	1/TSTOP
MOD_INDEX	YES	0
SIGNAL_FREQ	YES	1/TSTOP

TSTOP is the stop time specified on the TRAN analysis.

damped_sin

Examples:

```
ivs:vin n1 0 vt=damped_sin(time)
ics:iin n1 0 it=damped_sin(time, 0, 5V, 500MHz, 50ns, 200ns)
```

Arguments for damped_sin

Name	Optional	Default
TIME	NO	
OFFSET	YES	0
AMPLITUDE	YES	1
FREQ	YES	1/TSTOP
DELAY	YES	0
DAMPING	YES	1/TSTOP

TSTOP is the stop time specified on the TRAN analysis.

pulse

Examples:

```
ivs:vin n1 0 vt=pulse(time)
ics:iin n1 0 it=pulse(time, -5V, 5V, 500MHz, 50ns, 200ns)
```

Arguments for pulse

Name	Optional	Default
TIME	NO	
LOW	YES	0
HIGH	YES	1
DELAY	YES	0
RISE	YES	TSTEP
FALL	YES	TSTEP
WIDTH	YES	TSTOP
PERIOD	YES	TSTOP

TSTEP is the output step-time time specified on the TRAN analysis. TSTOP is the stop time specified on the TRAN analysis.

pwl

Examples:

```
ivs:vin n1 0 vt=pulse(time, 0, 0, 1ns, 1, 10ns, 1, 15ns, 0)
ics:iin n1 0 it=pwl(time, 0, 0, 1ns, 1, 5ns, 1, 5ns, 0.5,
10ns,0.5, 15ns, 0)
```

Arguments for pwl

Name	Optional	Default
TIME	NO	
T1	NO	
X1	NO	
T2	YES	NONE
X2	YES	NONE
.	.	.
.	.	.
.	.	.
TN	YES	NONE
XN	YES	NONE

Conditional Expressions

The ADS Simulator supports simple in-line conditional expressions:

```
if boolExpr then expr else expr endif
if boolExpr then expr elseif boolExpr then expr else expr
endif
```

boolExpr is a boolean expression, that is, an expression that evaluates to TRUE or FALSE.

expr is any non-boolean expression.

The *else* is required (because the conditional expression must always evaluate to some value).

There can be any number of occurrences of `elseif` *expr* `then` *expr*.

A conditional expression can legally occur as the right-hand side of an expression or function definition or, if parenthesized, anywhere in an expression that a variable can occur.

Boolean operators

equals	logical equals
=	logical equals
==	logical equals
notequals	logical not equals
!=	logical not equals
not	logical negative
!	logical negative
and	logical and
&&	logical and
or	logical or
||	logical or
<	less than
>	greater than
<=	less than or equals
>=	greater than or equals

Boolean expressions

A boolean expression must evaluate to TRUE or FALSE and, therefore, must contain a relational operator (`equals, =, ==, notequals, !=, <, >, <=,` or `>=`).

The only legal place for a boolean expression is directly after an `if` or an `elseif`.

A boolean expression cannot stand alone, that is,

```
x = a > b
```

is illegal.

Precedence

Tightest binding: `equals, =, ==, notequals, !=, >, <, >=, <=`

`NOT, !`

AND,

Loosest binding: OR, ||

All arithmetic operators have tighter binding than the boolean operators.

Evaluation

Boolean expressions are short-circuit evaluated. For example, if when evaluating *a* and *b*, expression *a* evaluates to FALSE, expression *b* will not be evaluated.

During evaluation of boolean expressions with arithmetic operands, the operand with the lower type is promoted to the type of the other operand. For example, in `3 equals x +j*b`, `3` is promoted to complex.

A complex number cannot be used with <, >, <=, or >=. Nor can an array (and remember that strings are arrays). This will cause an evaluation-time error.

Pointers can be compared only with pointers.

Examples:

Protect against divide by zero:

```
f(a) = if a equals 0 then 1.0e100 else 1.0/a endif
```

Nested if's #1:

```
f(mode) = if mode equals 0 then 1-a else f2(mode) endif
f2(mode) = if mode equals 1 then log(1-a) else f3(mode) endif
f3(mode) = if mode equals 2 then exp(1-a) else 0.0 endif
```

Nested if's #2:

```
f(mode) = if mode equals 0 then 1-a elseif mode equals 1 then \
log(1-a) elseif mode equals 2 then exp(1-a) else 0.0 endif
```

Soft exponential:

```
exp_max = 1.0e16
x_max = ln(exp_max)
exp_soft(x) = if x<x_max then exp(x) else
                                        (x+1-x_max)*exp_max endif
```

VarEqn Data Types

The 4 basic data types that *VarEqn* supports are integer, real, complex, and string. There is a fifth data type, pointer, that is also supported. Pointers are not allowed in an algebraic expression, except as an argument to a function that is expecting a pointer. Strings are not allowed in algebraic expressions either except that addition of strings is equivalent to catenation of the strings. String catenation is not commutative, and since *VarEqn's* simplification routines can internally change the order of operands of commutative operators, this feature should be used cautiously. It will most likely be replaced by an explicit catenation function.

Type conversion

The data type of a *VarEqn* expression is determined at the time the expression is evaluated and depends on the data types of the terms in the expression. For example, let y=3*x^2. If x is an integer, then y is integer-valued. If x is real, then y is real-valued. If x is complex, then y is complex-valued.

As another example, let `y=sqrt(2.5*x)`. If `x` is a positive integer, then `y` evaluates to a real number. If, however, `x` is a negative integer, then `y` evaluates to a complex number.

There are some special cases of type conversion:

- If either operand of a division is integer-valued, it is promoted to a real before the division occurs. Thus, `2/3` evaluates to `0.6666....`
- The built-in trigonometric, hyperbolic, and logarithmic functions never return an integer, only a real or complex number.

“C-Preprocessor”

Before being interpreted by the ADS Simulator, all input files are run through a built-in preprocessor based upon a C preprocessor. This brings several useful features to the ADS Simulator, such as the ability to define macro constants and functions, to include the contents of another file, and to conditionally remove statements from the input. All C preprocessor statements begin with # as the first character.

Unfortunately, for reasons of backward compatibility, there is no way to specify include directories. The standard C preprocessor “`-I`” option is not supported; instead, “`-I`” is used to specify a file for inclusion into the netlist.

File Inclusion

Any source line of the form

```
#include "filename"
```

is replaced by the contents of the file *filename*. The file must be specified with an absolute path or must reside in either the current working directory or in `/$HPEESOF_DIR/circuit/components/.`

Library Inclusion

The C preprocessor automatically includes a library file if the `-N` command line option is not specified and if such a file exists. The first file found in the following list is included as the library:

```
$HPEESOF_DIR/circuit/components/gemlib
$EESOF_DIR/circuit/components/gemlib
$GEMLIB
.gemlib
~/.gemlib
~/gemini/gemlib
```

A library file is specified by the user using the `-I`*filename* command line option. More than 1 library may be specified. Specifying a library file prevents the ADS Simulator from including any of the above library files.

Macro Definitions

A macro definition has the form;
`#define name replacement-text`

It defines a macro substitution of the simplest kind--subsequent occurrences of the token *name* are replaced by *replacement-text*. The name consists of alphanumeric characters and underscores, but must not begin with a numeric character; the replacement text is arbitrary. Normally the replacement text is the rest of the line, but a long definition may be continued by placing a "\" at the end of each line to be continued. Substitutions do not occur within quoted strings. Names may be undefined with
`#undef name`

It is also possible to define macros with parameters. For example,
`#define to_celcius(t) (((t)-32)/1.8)`

is a macro with the formal parameter `t` that is replaced with the corresponding actual parameters when invoked. Thus the line
`options temp=to_celcius(77)`

is replaced by the line
`options temp=(((77)-32)/1.8)`

Macro functions may have more than 1 parameter, but the number of formal and actual parameters must match.

Macros may also be defined using the `-D` command line option.

Conditional Inclusion

It is possible to conditionally discard portions of the source file. The `#if` line evaluates a constant integer expression, and if the expression is non-zero, subsequent lines are retained until an `#else` or `#endif` line is found. If an `#else` line is found, any lines between it and the corresponding `#endif` are discarded. If the expression evaluates to zero, lines between the `#if` and `#else` are discarded, while those between the `#else` and `#endif` are retained. The conditional inclusion statements nest to an arbitrary level of hierarchy. The following operators and functions can be used in the constant expression;

!	Logical negation.
||	Logical or.
&&	Logical and.
==	Equal to.
!=	Not equal to.
>	Greater than.
<	Less than.
>=	Greater than or equal to.
<=	Less than or equal to.
+	Addition.
defined(x)	1 if x defined, 0 otherwise.

The `#ifdef` and `#ifndef` lines are specialized forms of `#if` that test whether a name is defined.

CAUTION Execution of preprocessor instructions depend on the order in which they appear on the netlist. When using preprocessor statements make sure that they are in the proper order. For example, if an #ifdef statement is used to conditionally include part of a netlist, the corresponding #define statement is contained in a separate file and #include is used to include the content of the file into the netlist, the #include statement will have to appear before the #ifdef statement for the expression to evaluate correctly.

Data Access Component

The Data Access Component provides a clean, unified way to access tabular data from within a simulation. The data may reside in either a text file of a supported, documented format (e.g. discrete MDIF, model MDIF, Touchstone, CITIfile), or a dataset. It provides a variety of access methods, including lookup by index/value, as well as linear, cubic spline and cubic interpolation modes, with support for derivatives.

The Data Access Component provides a "handle" with which one may access data from either a text file or dataset for use in a simulation. The DAC is implemented as a cktlib subcircuit fragment with internally known expressions names (e.g. _DAC, _TREE) that are assigned via *VarEqn* calls such as `read_data()` and `access_all_data()`. The accessed data can be used by other components (including models, devices, variables, subcircuit calls and other DAC instances) in the netlist, either by the specific file syntax or via the *VarEqn* function `dep_data()`.

The DAC can also be used to supply parameters to device and model components from text files and datasets. In this case, the `AllParams` device/model parameter is used to refer to a DAC component. The component's parameters will then be accessed from the DAC and supplied to the instance. Care is taken to ensure that only matching (between parameter names in the component definition and DAC dependent column names) data is used. Also, parameter data can be assigned "inline" - as is usually done - in which case the inline data takes precedence over the DAC data.

As the DAC component is composed of just a parameterized subcircuit, it allows alterations (sweep, tune, optimize, yield) of its parameters. Consequently any component that uses DAC data via file, `dep_data()` or `AllParams` will automatically be updated when a DAC parameter is altered. A caveat with sweeping over files using `AllParams` is that all the files must contain the same number of dependent columns of data.

Below is an example definition of a simple DAC component that accesses discrete values from a text file:

```
#uselib "ckt" , "DAC"
DAC:DAC1  File="C:\jeffm\ADS_testing\ADS13_test_prj/
.\data\SweptData.ds"
Type="dataset" Block="S" InterpMode="linear" InterpDom="ri"
iVar1="X" iVal1=X iVar2="freq" iVal2=freq
S_Port:S2P1  _net1 0 _net6 0 S[1,1]=file{DAC1, "S[1,1]"}
S[1,2]=file{DAC1,"S[1,2]"} S[2,1]=1 S[2,2]=0 Recip=no

dindex = 1
DAC:atc1 File="vdcr.mdf" Type="dscr" \
 InterpMode="index_lookup" iVar1=1 iVal1=dindex
```

And its use to provide the resistance value to a pair of circuit components:

```
R:R1 n1 0 R=file{atc1, "R"} kOhm
R:R2 n1 0 R=dep_data(atc1, "R") kOhm
Here, it provides the value to a variable:
V1 = file{atc1, "Vdc"}
```

V1 could be used elsewhere in the circuit, as expected.

In this example, a scaling factor applied to the result of a DAC access is shown:

```
File = "atc.mdf"
Type = "dscr"
Mode="index_lookup"
Cnom = "Cnom"
DAC:atc_s File=File Type=Type InterpMode=Mode iVar1=1
iVal1 = Cs_row
C:Cs n1 n2 C=file{atc_s, Cnom} Pf
```

In this example, a use of `AllParams` is shown to enter model parameters from a text file:

```
File = "c:\gemini\vdcr.mdf"
Type = "dscr"
Mode="index_lookup"
DAC:dac1 File=File Type=Type InterpMode=Mode iVar1=1
iVal1 = ix
model rm1 R_Model R=0 AllParams = dac1._DAC
rm1:rm1i1 n3 0
```

Reserved Words

The words on the following pages have built-in meaning and should not be defined or used in a way not consistent with their pre-defined meaning:

AC
ACPWDS
ACPWDTL
AIRIND1
Alter
Amplifier
AmplifierP2D
AntLoad
BFINL
BFINLT
BJT
BR3CTL
BR4CTL
BRCTL
BROCTL
Bessel
BudLinearization
Butterworth
C
CAPP2
CAPQ
CIND2
CLIN
CLINP
COAX
COAXTL
CPW
CPWCPL4
CPWCTL
CPWDS
CPWEF
CPWEGAP
CPWG
CPWOC
CPWSC
CPWSUB
CPWTL
CPWTLFG
CTL
C_Model
Chain
Chebyshev
Connector
CostIndex
Crossover
DC
DF
DFDevice1
DFDevice2
DF_DefaultInt
DF_Value
DF_ZERO_OHMS
DICAP
DILABMLC

CPWCGAP
CPWCPL2
DefaultValue
DeviceIndex
Diode
EE_BJT2
EE_FET3
EE_HEMT1
EE_MOS1
ETAPER
Elliptic
FDD
FINLINE
FSUB
GCPWTL
GMSK_Lowpass
GaAs
Gaussian
Goal
HB
HP_Diode
HP_FET
HP_FET2
HP_MOSFET
Hybrid
IFINL
IFINLT
INDQ
I_Source
InitCond
InoiseBD
MOS9
MOSFET
DOE
DRC
JFET
L
LineCalcTest
MACLIN
MACLIN3
MBEND
MBEND2
MBEND3
MBSTUB
MCFIL
MCLIN
MCORN
MCROS
MCROSO
MCURVE
MCUREVE2
MGAP
MICAP1
MICAP2
MICAP3
MICAP4
MLANG
MLANG6
MLANG8
MLEF
MLIN
MLOC
MLSC
MLYRSUB
MSRTL
MSSLIT

MRIND
MRINDELA
MRINDELM
MRINDNBR
MRINDSBR
MRINDWNR
MRSTUB
MS2CTL
MS3CTL
MS4CTL
MS5CTL
MSABND
MSACTL
MSAGAP
MSBEND
MSCRNR
MSCROSS
MSCTL
MSGAP
MSIDC
MSIDCF
MSLANGE
MSLIT
MSOBND
MSOC
MSOP
MSRBND
OldOptim
OldYield
Optim
OptimGoal
Options
OscPort
MSSPLC
MSSPLR
MSSPLS
MSSTEP
MSSVIA
MSTAPER
MSTEE
MSTEP
MSTL
MSUB
MSVIA
MSWRAP
MTAPER
MTEE
MTEEO
MTFC
MextramBJT
Mixer
MixerIMT
Multipath
Mutual
NodeSet
NoiseCorr2Port
Noisey2Port
Nsample
OldMonteCarlo
OldOpt
PC_Corner
PC_CrossJunction
PC_Crossover
PC_Gap
PC_Line
PC_OpenStub

OutSelector
PCBEND
PCCORN
PCCROS
PCCURVE
PCILC
PCLIN1
PCLIN10
PCLIN2
PCLIN3
PCLIN4
PCLIN5
PCLIN6
PCLIN7
PCLIN8
PCLIN9
PCSTEP
PCSUB
PCTAPER
PCTEE
PCTRACE
PC_Bend
PC_Clear
RWGTL
R_Model
RaisedCos
SAGELIN
SAGEPAC
SBCLIN
SBEND
SBEND2
SCLIN
SCROS
PC_Pad
PC_Slanted
PC_Taper
PC_Tee
PC_Via
PIN
PIN2
PLCQ
ParamSweep
PinDiode
PoleZero
Polynomial
Port
PowerBounce
PowerGroundPlane
R
RCLIN
RIBBON
RIBBON_MDS
RIND
RWG
RWGINDF
RWGT
SLSTEP
SLTEE
SLTL
SLUCTL
SLUTL
SMITER
SOCLIN
SPIND
SS3CTL
SS4CTL

SCURVE
SDD
SL3CTL
SL4CTL
SL5CTL
SLABND
SLCQ
SLCRNR
SLCTL
SLEF
SLGAP
SLIN
SLINO
SLOBND
SLOC
SLOC_MDS
SLOTTL
SLRBND
SLSC
Short
Substrate
SweepPlan
SwitchV
SwitchV_Model
TAPIND1
TFC
TFC_MDS
TFR
TFR_MDS
TL
TLIN
TLIN4
TLINP
SS5CTL
SSACTL
SSCLIN
SSCTL
SSLANGE
SSLIN
SSSPLC
SSSPLR
SSSPLS
SSSUB
SSTEP
SSTFR
SSTL
SSUB
SSUBO
STEE
S_Param
S_Port
ScheduleCycle
VBIC
VIA
VIA2
V_Source
VnoiseBD
WIRE
WIRE_MDS
Y_Port
Yield
YieldOptim
YieldSpec
YieldSpecOld
Z_Port
__fdd

TLINP4
TL_New
TQAVIA
TQCAP
TQFET
TQFET2
TQIND
TQRES
TQSVIA
TQSWH
TQTL
Tran
UFINL
UFINLT
Unalter
_c21
_c22
_c23
_c24
_c25
_c26
_c27
_c28
_c29
_c3
_c30
_c4
_c5
_c6
_c7
_c8
_c9
_dc_state
__fdd_v
_ac_state
_c1
_c10
_c11
_c12
_c13
_c14
_c15
_c16
_c17
_c18
_c19
_c2
_c20
_freq6
_freq7
_freq8
_freq9
_gaussian
_gaussian_tol
_get_fnom_freq
_get_fund_freq_for_fdd
_harm
_hb_state
_i1
_i10
_i11
_i12
_i13
_i14
_i15
_i16

_default
_discrete_density
_divn
_freq1
_freq10
_freq11
_freq12
_freq2
_freq3
_freq4
_freq5
_i27
_i28
_i29
_i3
_i30
_i4
_i5
_i6
_i7
_i8
_i9
_lfsr
_mvgaussian
_mvgaussian_cov
_n_state
_nfmin
_p2dInputPower
_phase_freq
_pwl_density
_pwl_distribution
_randvar
_rn
_i17
_i18
_i19
_i2
_i20
_i21
_i22
_i23
_i24
_i25
_i26
_sopt
_sp_state
_sv
_sv_bb
_sv_d
_sv_e
_tn
_to
_tr_state
_tt
_uniform
_uniform_tol
_v1
_v10
_v11
_v12
_v13
_v14
_v15
_v16
_v17
_v18

_shift_reg
_si
_si_bb
_si_d
_si_e
_sigproc_state
_sm_state
_v25
_v26
_v27
_v28
_v29
_v3
_v30
_v4
_v5
_v6
_v7
_v8
_v9
_xcross
abs
access_all_data
access_data
aele
and
arcsinh
arctan
atan2
awg_dia
bin
bitseq
boltzmann
_v19
_v2
_v20
_v21
_v22
_v23
_v24
conj
cos
cos_pulse
cosh
cot
coth
coupling
ctof
ctok
cxform
d_atan2
damped_sin
db
dbm
dbmtoa
dbmtov
dbmtow
dbpolar
dbwtow
dcSourceLevel
deembed
define
deg
delay
dep_data
deriv

by
c0
complex
doeindex
dphase
dsexpr
dstoarray
e
e0
echo
else
elseif
end
endif
equals
erf_pulse
eval_poly
exp
exp_pulse
file
fread
freq
freq_mult_coef
freq_mult_poly
ftoc
ftok
gauss
gaussian
generate_gmsk_iq_spectra
generate_gmsk_pulse_spectra
generate_piqpsk_spectra
generate_pulse_train_spectra
interp2
discrete
distcompname
doe
generate_qam16_spectra
generate_qpsk_pulse_spectra
get_array_size
get_attribute
get_block
get_fund_freq
get_max_points
global
globalnode
ground
hugereal
i
if
ilsb
imag
index
innerprod
inoise
int
internal_generate_gmsk_iq_spectra
internal_generate_gmsk_pulse_spectra
internal_generate_piqpsk_spectra
internal_generate_pulse_train_spectra
internal_generate_qam16_spectra
internal_generate_qpsk_pulse_spectra
internal_get_fund_freq
internal_window
interp
interp1
names

interp3
interp4
iss
itob
iusb
jn
ktoc
ktof
lbtran
length
limit_warn
list
ln
ln10
local
log
logNodesetScale
logRshunt
log_amp
log_amp_cas
mag
makearray
max
mcTrial
mcindex
min
model
multi_freq
qinterp
rad
ramp
randtime
rawtoarray
nested
nf
nfmin
no
nodoe
noisefreq
noopt
norm
nostat
not
notequals
omega
opt
optIter
or
parameters
phase
phase_noise_pwl
phasedeg
phaserad
planck
polar
polarcpx
ppt
pulse
pwl
pwlr
qelectron
sprintf
sqrt
ssfreq
stat
step

read_data
read_lib
readdata
readlib
readraw
real
rect
rem
ripple
rms
rn
rpsmooth
scalearray
sens
setDT
sffm
sgn
sin
sinc
sine
sinh
sink
sopt
sourceLevel
vnoise
vss
vswrpolar
vusb
window
yes
strcat
stypexform
sym_set
system
tan
tanh
temp
tempkelvin
thd
then
time
timestep
tinyreal
to
toi
tranorder
transform
u0
unconst
unicap
uniform
v
value
vlsb

8
IC-CAP Functions

This chapter describes the IC-CAP functions. They appear in alphabetical order.

When reviewing the functions, keep in mind the following points:

- Many functions can be called from within a Program or Macro. Several examples are provided here; additional examples can be found in "Calls to the Function Library" on page 749.
- The list does not represent all the functions available in a Program or Macro. Additional *built-in* functions are available in the Parameter Extraction Language. Refer to "Built-in Functions" on page 712.
- For consistency, the argument names listed for each function reflect the descriptive labels these arguments would get in a standalone Transform editor.
- The Input Arguments referred to as *Strings/Pars/Vars* can be any of the following alternatives: string expressions, Model parameter names, DUT parameter names, or IC-CAP system variable names.

The tables that follow list the available functions by category, as they appear in the program.

Table 72 IC-CAP Functions

AHBT

AgilentHBT_ABCX_extract
AgilentHBT_calculate_ccb
AgilentHBT_calculate_rbb
AgilentHBT_CCMAX_extract
AgilentHBT_CEMAX_extract
AgilentHBT_CJC_extract
AgilentHBT_CJE_extract
AgilentHBT_IS_NF_extract
AgilentHBT_ISC_NC_extract
AgilentHBT_ISE_NE_extract
AgilentHBT_ISH_NH_extract
AgilentHBT_ISR_NR_extract
AgilentHBT_ISRH_NRH_extract
AgilentHBT_ITC_ITC2_extract
AgilentHBT_Param_Init
AgilentHBT_TFC0_extract
AgilentHBT_VJC_extract
AgilentHBT_VJE_extract

ATFT (obsolete)

HPTFTCV_model_cgd
HPTFTDC_lin
HPTFTDC_sat
HPTFTCV_model_cgs
HPTFTDC_model_id
HPTFT_param

B2200

B2200_bias_card_enable
B2200_bias_ch_enable
B2200_bias_enable
B2200_bias_init
B2200_close_interface
B2200_connect
B2200_couple_enable
B2200_couple_setup
B2200_debug
B2200_disconnect_card
B2200_GPIB_handler
B2200_ground_card_enable
B2200_ground_enable
B2200_ground_init
B2200_ground _outch_enable
B2200_ground _unused_inputs
B2200_init
B2200_open_interface

BJT

BJTAC_high_freq
BJTDC_rc
BJTCV_stoc
BJTAC_rb_rbm_irb
BJTDC_rcfb
RBBcalc
BJTDC_fwd_gummel
BJTDC_re
H11corr
BJTDC_is_nf
BJTDC_rev_gummel
BJT_dc_model
BJTDC_nr
BJTDC_vaf_var
HFBJT_linear_ssmod_sim
HFBJT_linear_elem_extr

BPOPAMP

BPOPAMP_macro_model

BSIM1 (obsolete)

BSIM1DC_geom_indep
BSIM1DC_sub
BSIMCV_total_cap
BSIM1DC_lin_sat

BSIM2 (obsolete)

BSIM2DC_geom_indep
BSIM2_save_dev_pars
BSIM2_lin_plot
BSIM2DC_lin_sat
BSIMCV_total_cap

Table 72 IC-CAP Functions (continued)

BSIM3

BSIM3_set_opt
BSIM3DC_bulk_short
BSIM3DC_lin_large
BSIM3DC_lin_narrow
BSIM3DC_lin_short
BSIM3DC_lin_small
BSIM3_calculate
BSIM3_DC_vth
BSIM3_DC_calc_bin_parameter
BSIM3DC_sat_narrow
BSIM3DC_sat_short
BSIM3DC_sat_short2
BSIM3DC_sub_short
BSIM3DC_sub_short2
BSIM3DC_model
BSIM3_toolkit_vth
BSIM3_DC_calculate
BSIM3_error
BSIM3DC_vth
BSIM3DC_vth_sim
BSIM3DC_vth_versus
BSIM3CVmodCBD
BSIM3CVmodCBS
BSIM3CV_total_cap
BSIM3_check_par
BSIM3_DC_get_parameter

BSIM4

BSIM4_check_par
BSIM4_DC_calculate
BSIM430_DC_calculate
BSIM450_DC_calculate
BSIM4_DC_calc_bin_parameter
BSIM4_DC_get_parameter
BSIM4_DC_extr_A0_AGS_KETA
BSIM4_DC_vth
BSIM430_DC_vth
BSIM450_DC_vth
BSIM4_error
BSIM4_set_opt

Data Exchange

ICMSarray
ICMSchar
ICMSint
LINKint
LINKstr
ICMSpin
ICMSreal
ICMSstr
LINKpin
SPECSSpin
LINKarray
LINKchar
LINKreal

Data Export

icdb_add_comment
icdb_get_sweep_value
icdb_register_lin_sweep
icdbf_close
icdbf_open
icdbf_register_list_sweep
icdb_close
icdb_open
icdb_register_list_sweep
icdbf_export_data
icdbf_register_con_sweep
icdb_register_lsync_sweep
icdb_export_data
icdb_register_con_sweep
icdbf_add_comment
icdbf_get_sweep_value
icdbf_register_lin_sweep
icdbf_register_lsync_sweep

Data Fit

autofit
fit_line
circlefit
linfit

Table 72 IC-CAP Functions (continued)

Diode

DIODEDCmod_ia

EEBJT

EEbjt2_Is_N
EEbjt2_ce_dc_iv
EEbjt2_ce_ss_elements
EEbjt2_extrinsic_ckt
EEbjt2_mdl
HFMOD_get_bias_size
HFMOD_get_freq_index
HFMOD_get_freq_value
HFMOD_remove_freq_dbl
HFMOD_remove_freq_mat

EEFET

EEfet3_ckt
EEfet3_model_name
EEfet3_Rs_delta_s
EEfet3_cs_dc_iv
EEfet3_package
EEfet3_s2ckt
EEfet3_Iecp
EEfet3_ResCheck
EEfet3_spars
EEfet3_mdl
EEfet3_Rs_delta_m

EEMOS (obsolete)

EEmos1_ckt
EEmos1_mdl
EEmos1_ResCheck
EEmos1_cs_dc_iv
EEmos1_model_name
EEmos1_s2ckt
EEmos1_Iecp
EEmos1_package
EEmos1_spars

Flicker Noise

NOISE_1f_bjt_1Hz
NOISE_1f_bjt_calc
NOISE_1f_bjt_extract
NOISE_1f_force_bias
NOISE_1f_get_Af
NOISE_1f_get_Bf
NOISE_1f_get_Ef
NOISE_1f_get_Kf
NOISE_1f_mos_1Hz
NOISE_1f_set_Af
NOISE_1f_set_Bf
NOISE_1f_set_Ef
NOISE_1f_set_Kf
NOISE_1f_stop_bias

GAAS

GAASAC_cur
GAASDC_lev1
GAASmod_cgd
GAASAC_I_and_r
GAASDC_lev2
GAASmod_cgs
GAASAC_r_and_c
GAASDC_rd
GAASmod_id
GAASCV_cgs_cgd
GAASDC_rs
GAASmod_ig
GAASDC_cur1
GAASAC_calc_rc
GAASAC_calc_rI
GAASDC_cur2

General Math

RMSerror
conjg
log10
TwoPort
correlation
mean

Table 72 IC-CAP Functions (continued)

TwoPort2	cos	random
abs	cosh	sin
acs	derivative	sinh
acsh	derivative2	smooth3
arg	equation	sqrt
asn	exp	tan
asnh	log	tanh
atn	floor	variance
atnh	integral0	mem_diag
ceil	integral3	
HF MOS Level3 (obsolete)		
HFMOS3_capas	HFMOS3_paras	HFMOS3_StoC
HFMOS3_lin_large	HFMOS3_sat_short	HFMOS3_StoZ
HFMOS3_lin_narrow	HFMOS3_sub_large	HFMOS3_modcap
HFMOS3_lin_short	HFMOS3_total_cap	
HPIB		
HPIB_abort	HPIB_open	HPIB_spoll
HPIB_clear	HPIB_read_reals	HPIB_srq
HPIB_close	HPIB_readnum	HPIB_timeout
HPIB_command	HPIB_readstr	HPIB_write
HPIB_eoi	HPIB_fwrite	HPIB_read
HPMOS		
HPMOSDC_lin_large	HPMOSDC_lin_short	HPMOS_process_pars
HPMOSDC_lin_narrow	HPMOSDC_sat_short	
HPRoot Diode		
HPdiode_C	HPdiode_S11i	HPdiode_para_at_f
HPdiode_C2	HPdiode_S11r	HPdiode_para_f
HPdiode_I	HPdiode_V	HPdiode_wr
HPdiode_Q	HPdiode_data_acqu	HPRoot_n
HPdiode_R	HPdiode_mdl	HPdiode_fgrt
HPdiode_fless	HPdiode_iextr	
HPRoot Fet		

Table 72 IC-CAP Functions (continued)

HPRoot_data_acqu	HPRoot_Qd	HPRoot_Y12r
HPRoot_FET	HPRoot_Qg	HPRoot_Y21i
HPRoot_initial	HPRoot_Vd	HPRoot_Y21r
HPRoot_parasitic	HPRoot_Vg	HPRoot_Y22i
HPRoot_Id	HPRoot_Y11i	HPRoot_Y22r
HPRoot_Idh	HPRoot_Y11r	HPRoot_FET_t
HPRoot_Ig	HPRoot_Y12i	HPRoot_fet_acqu
HPRoot_n	HPRoot_para_cal	HPRoot_wr
HPRoot Mos		
HPRoot_Id	HPRoot_Vd	HPRoot_Y12r
HPRoot_Idh	HPRoot_Vg	HPRoot_Y21i
HPRoot_Ig	HPRoot_Y11i	HPRoot_Y21r
HPRoot_Qd	HPRoot_Y11r	HPRoot_Y22i
HPRoot_Qg	HPRoot_Y12i	HPRoot_Y22r
HPRoot_MOSFET	HPRoot_mos_acqu	HPRoot_mos_para
HPRoot_para_cal		
JUNCAP		
JUNCAP	JUNCAP_TR	
MEXTRAM		
MXT_I0	MEXTRAM_stoc	MXT_cbc
MXT_cbe	MXT_cj0	MXT_csc
MXT_forward_hfe	MXT_forward_ic	MXT_forward_vbe
MXT_ft	MXT_VEF	MXT_ic_vce
MXT_VER	MXT_hard_sat_isub	MXT_reverse_isub
MXT_jun_cap	MXT_reverse_currents	MXT_reverse_hfc
MXT_reverse_hfc_sub	MXT_veaf_ib	MXT_veaf_ic
MXT_vear_ie	MXT_show_parms	
MEXTRAM 503 (obsolete)		
mxt_smooth	mxt3t_cbc	mxt3t_cbe
mxt3t_cj0	mxt3t_ft_ic	mxt3t_ft_ic_new
mxt3t_fwd_early_ib	mxt3t_fwd_early_ic	mxt3t_fwd_gummel_hfe
mxt3t_fwd_gummel_ib	mxt3t_fwd_gummel_ic	mxt3t_fwd_gummel_vbe

Table 72 IC-CAP Functions (continued)

mxt3t_i0	mxt3t_linear_range	mxt3t_output_ic
mxt3t_output_vbe	mxt3t_rev_early_ie	mxt3t_rev_early_qb0_guess
mxt3t_rev_gummel_hfc	mxt3t_rev_gummel_ib	mxt3t_rev_gummel_ie
mxt4t_cbc	mxt4t_cbe	mxt4t_cj0
mxt4t_csc	mxt4t_ft_ic	mxt4t_ft_ic_new
mxt4t_fwd_early_ib	mxt4t_fwd_early_ic	mxt4t_fwd_gummel_hfe
mxt4t_fwd_gummel_ib	mxt4t_fwd_gummel_ic	mxt4t_fwd_gummel_vbe
mxt4t_i0	mxt4t_linear_range	mxt4t_output_ic
mxt4t_output_vbe	mxt4t_rev_early_ie	mxt4t_rev_early_qb0_guess
mxt4t_rev_gummel_hfc	mxt4t_rev_gummel_hfc_sub	mxt4t_rev_gummel_ib
mxt4t_rev_gummel_ie	mxt4t_rev_gummel_is	
MM9		
MM9_LIN_EXT	MM9_COPY	MM9_SAVE_SPARS
MM9_SAT_EXT	MM9_DATA	MM9_SETUP
MM9_STH_EXT	MM9_GEOMPAR	MM9_TEMPPAR
MM9_WEAVAL_EXT	MM9_GEOMSCAL	MM9_TEMPSCAL
MM9	MM9_KEEP	
MOS Level1		
MOSmodel	MOSmodel2	
MOS Level2		
MOSCV_total_cap	MOSDC_lev2_lin_short	MOSCVmodCBS
MOSDC_lev2_lin_large	MOSDC_lev2_sat_short	MOSmodel
MOSDC_lev2_lin_narrow	MOSCVmodCBD	MOSmodel2
MOS Level3		
MOSCV_total_cap	MOSDC_lev3_lin_short	MOSCVmodCBS
MOSDC_lev3_lin_large	MOSDC_lev3_sat_short	MOSmodel2
MOSDC_lev3_lin_narrow	MOSCVmodCBD	
MOS Level6		
MOSCV_total_cap	MOSDC_lev6_lin_narrow	MOSCVmodCBD
MOSDC_lev6_lin_large	MOSDC_lev6_lin_short	MOSCVmodCBS
MOS Process		
MOS_process_pars		

Table 72 IC-CAP Functions (continued)

Optimization

Optimize

PEL

Program or Program2

PN Capacitance

PNCAPsimu

PSP

PSP_DC_vth | PSP_check_par | PSP_DC_calc_bin_parameter

PSP_set_opt

PTFT (obsolete)

PTFTCV_cgd | PTFTDC_lin | PTFTDC_sat

PTFTCV_cgs

Random Functions

rand_flat | rand_gauss | rand_seed

Statistical Analysis

icstat_get_column | icstat_deactivate | icstat_set_text_cell

icstat_set_column | icstat_attribute_2_parameter | icstat_open

icstat_num_columns | icstat_parameter_2_attribute | icstat_write_to_status_window

icstat_num_rows | icstat_analysis | icstat_exit

icstat_get_cell | icstat_correlation | icstat_open_sdf_file

icstat_set_cell | icstat_stat_summary | icstat_close_sdf_file

icstat_num_deactivated | icstat_factor_analysis | icstat_save_sdf_file

icstat_num_filtered | icstat_parametric_models | icstat_to_partable

icstat_num_attributes | icstat_equations | icstat_from_partable

icstat_get_deactivated | icstat_plot_graph | icstat_set_param_column_labels

icstat_get_filtered_rows | icstat_set_row | iicstat_nonparametric_models

icstat_get_attribute_columns | icstat_get_row | icstat_clear

icstat_activate | icstat_get_text_cell | icstat_delete

icstat_insert

Switching Matrix

Connect | SWM_debug | Wait

FNPort | SWM_init | HP5250_bias_card

Table 72 IC-CAP Functions (continued)

HP5250_card_config	HP5250_bias_channel	HP5250_bias_init
HP5250_bias_setmode	HP5250_compensate_cap	HP5250_connect
HP5250_couple_enable	HP5250_couple_setup	HP5250_debug
HP5250_disconnect_card	HP5250_init	HP5250_show
K707_init	K708a_init	K70X_clear_setup
K70X_close_crosspoints	K70X_config_trigger	K70X_connect_sequence
K70X_copy_setup	K70X_debug	K70X_delete_setup
K70X_edit_setup	K70X_init_interface	K70X_open_crosspoints
K70X_trigger_disable	K70X_trigger_enable	

Target

TARGET_DC_vth

TRL Calibration

8753_TRL_Cal	TRL_Cal	

USERC

USERC_init_param	USERC_open	USERC_sweep_start
USERC_avg_2	USERC_read_reals	USERC_sweep_stepsize
USERC_avg_3	USERC_readnum	USERC_sweep_stop
USERC_conjg	USERC_readstr	USERC_system
USERC_transpose	USERC_seek	USERC_tell
USERC_close	USERC_set_param	USERC_write
USERC_data_w_check	USERC_size	USERC_sweep_name
USERC_num_of_points	USERC_set_param_quiet	USERC_sweep_mode
USERC_get_object_name		

User Defined

Holding place for user-defined functions. For details, refer to "Adding Functions to the Function Browser" in the *User's Guide*.

Utility

check_error_log	copy2output	Package
dataset	lookup_par	lookup_var
ascii$		

VBIC

VBIC_ac_solver	VBIC_avc	VBIC_cbc
VBIC_cbe	VBIC_cj0	VBIC_clean_data

Table 72 IC-CAP Functions (continued)

VBIC_csc	VBIC_dc_approx	VBIC_dci_solver
VBIC_dcv_solver	VBIC_fg_currents	VBIC_ibci_nci
VBIC_ibei_nei	VBIC_ikf	VBIC_stoc
VBIC_ikr	VBIC_is_nf	VBIC_isp_nfp
VBIC_nr	VBIC_qcdepl	VBIC_rcx
VBIC_rg_currents	VBIC_vef_ver	
Wafer Prober		
Pdown	Porig	Prober_status
Phome	Ppos	Pscale
Pimove	Prober_debug	Pup
Pink	Prober_init	PB_bindex
Pmove	Prober_reset	PB_gsite_xy
PB_abort	PB_bincode	PB_msite_xy
PB_bindex_cr	PB_index_cr	PBench_CMD
PB_index	PB_gindex_cr	tis_p_down
tis_p_home	tis_p_imove	tis_p_ink
tis_p_move	tis_p_orig	tis_p_pos
tis_p_scale	tis_p_up	tis_prober_get_ba
tis_prober_get_name	tis_prober_init	tis_prober_read_sysconfig
tis_prober_reset	tis_prober_status	
Wire Functions		
wirexfX	wirexfY	wirexfYX
wirexfXY		

8753_TRL_Cal Deembed the raw measured data using measured data of TRL (thru-reflect-line) calibration standards. The function calculates and downloads the error coefficients to the 8753. The reference plane is defined at the middle of the thru standard, or at the interface to the DUT when it is installed in the compatible carrier.

Inputs:

Freq Data: Frequency Inputs

Thru:	measured S-parameters of the Thru standard
Short:	measured S-parameters of the Short standard
Line A:	measured S-parameters of Line A standard
Line B:	measured S-parameters of Line B standard
Line C:	measured S-parameters of Line C standard
Freq 1 Trans:	transition frequency Line A to Line B
Freq 1 Trans:	transition frequency Line B to Line C
Outputs:	None

abs Absolute value function (magnitude when input data is complex)

Input Arguments:

Data Sets:	Input 1
Output:	Real number, matrix, real array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

acs Inverse cosine in radians.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

acsh Inverse hyperbolic cosine.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

AgilentHBT_ABCX_extract This function extracts model parameter ABCX.

Input Arguments:

Variables:	Emitter Area, Total Area
Parameters:	Parameter(ABCX)
Extracts:	ABCX

AgilentHBT_calculate_ccb This function calculates Cbc in an alternative method from the specified Z-parameters.

Input Arguments:

Inputs:	freq, Z11, Z12, Z21, Z22
Output:	Complex data sets.

AgilentHBT_calculate_rbb This function calculates Rb in an alternative method from the specified H-parameters.

Input Arguments:

Inputs:	freq, H11, H12, H21, H22
Variables:	Mode (0:ignore RE effect, 1:include RE effect)
Parameters:	Parameter(RE)
Output:	Complex data sets

AgilentHBT_CCMAX_extract This function extracts model parameter CCMAX.

Input Arguments:

Inputs:	Vbc (as positive value), Cbc
Parameters:	Parameter(CCMAX), Parameter(VJC)
Extracts:	CCMAX

AgilentHBT_CEMAX_extract This function extracts model parameter CEMAX.

Input Arguments:

Inputs:	Vbe, Cbe
Parameters:	Parameter(CEMAX), Parameter(VJE)
Extracts:	CEMAX

AgilentHBT_CJC_extract This function extracts model parameter CJC.

Input Arguments:

Inputs:	Vbc (as positive value), Cbc
Parameters:	Parameter(CJC), Parameter(CPBC)
Extracts:	CJC

AgilentHBT_CJE_extract This function extracts model parameter CJE.

Input Arguments:

Inputs:	Vbe, Cbe
Parameters:	Parameter(CJE), Parameter(CPBE)
Extracts:	CJE

AgilentHBT_IS_NF_extract This function extracts model parameters IS, NF.

Input Arguments:

Inputs:	Vbe, Ic
Variables:	X Low, X High, Y Low, Y High, TEMP
Parameters:	Parameter(IS), Parameter(NF)
Extracts:	IS, NF

AgilentHBT_ISC_NC_extract This function extracts model parameters ISC, NC.

Input Arguments:

Inputs:	Vcb (as positive value), Ib
Variables:	X Low, X High, Y Low, Y High, TEMP
Parameters:	Parameter(ISC), Parameter(NC)
Extracts:	ISC, NC

AgilentHBT_ISE_NE_extract This function extracts model parameters ISE, NE.

Input Arguments:

Inputs:	Vbe, Ib
Variables:	X Low, X High, Y Low, Y High, TEMP
Parameters:	Parameter(ISE), Parameter(NE)
Extracts:	ISE, NE

AgilentHBT_ISH_NH_extract This function extracts model parameters ISH, NH.

Input Arguments:

Inputs:	Vbe, Ib
Variables:	X Low, X High, Y Low, Y High, TEMP
Parameters:	Parameter(ISH), Parameter(NH)
Extracts:	ISH, NH

AgilentHBT_ISR_NR_extract This function extracts model parameters ISR, NR.

Input Arguments:

Inputs:	Vcb (as positive value), Ie
Variables:	X Low, X High, Y Low, Y High, TEMP
Parameters:	Parameter(ISR), Parameter(NR)
Extracts:	ISR, NR

AgilentHBT_ISRH_NRH_extract This function extracts model parameters ISRH, NRH.

Input Arguments:

Inputs:	Vcb (as positive value), Ib
Variables:	X Low, X High, Y Low, Y High, TEMP
Parameters:	Parameter(ISRH), Parameter(NRH)
Extracts:	ISRH, NRH

AgilentHBT_ITC_ITC2_extract This function extracts model parameters ITC, ITC2.

Input Arguments:

Inputs:	Ic, Ft, Vc, Vb
Variables:	X Low, X High, Y Low, Y High
Parameters:	Parameter(ITC), Parameter(ITC2)
Extracts:	ITC, ITC2

AgilentHBT_Param_Init This function initializes the model parameters for the extraction.

Input Arguments:

Variables:	Emitter Width (W) [um] Emitter Length (L) [um] # of Emitter Fingers (NF) Total Area [um^2]
Parameters:	Parameter(hbt.TNOM)
Extracts:	All Agilent-HBT model parameters

AgilentHBT_TFC0_extract This function extracts model parameter TFC0.

Input Arguments:

Inputs:	Ic or Ic^{-1}, Tau, Vc, Vb
Variables:	X Low, X High, Y Low, Y High
Parameters:	Parameter(TFC0)
Extracts:	TFC0

AgilentHBT_VJC_extract This function extracts model parameter VJC.

Input Arguments:

Inputs:	Vbc (as positive value), Cbc, Cdiff
Parameters:	Parameter(VJC), Parameter(CJC), Parameter(CPBC)
Extracts:	VJC

AgilentHBT_VJE_extract This function extracts model parameter VJE.

Input Arguments:

Inputs:	Vbe, Cbe, Cdiff
Parameters:	Parameter(VJE), Parameter(CJE), Parameter(CPBE)
Extracts:	VJE

arg Argument (phase angle), in radians, for a complex number.

Input Arguments:

Data Sets:	Input 1
Output:	Real number, matrix, real array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

ascii$ *C*onverts ascii-coded characters into literal characters as entered into a text box.

If certain characters are entered in a text box, they must be encoded so they are compatible with the *.mdl* file format used in variable tables. These characters include double quotes (“) and newlines (\n). Such characters may be

entered in a GUI's edit box and tracked by a variable table variable. IC-CAP must encode these characters before storing them in a *.mdl* file to avoid undesirable effects.

After the characters are encoded, they appear as encoded characters if you choose to print them from the *.mdl* file to an output such as the Status window. To translate the encoding, call the function *ascii$()* in PEL and the string will be output exactly as it was typed into the text box.

asn Inverse sine in radians.

Input Arguments:	
Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

asnh Inverse hyperbolic sine.

Input Arguments:	
Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

atn Inverse tangent in radians.

Input Arguments:	
Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)

Automatic Invocation: On Data Set Input Change

atnh Inverse hyperbolic tangent.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

autofit Performs an automatic line fit to a set of X and Y data sets. This function finds the largest region of the line that fits with less than the specified error from the RMS limit field. A buffer can be specified that removes a certain percentage of the data from each end of the curve. This eliminates data points that may throw off the line fit. The percentages should be specified out of 1. For example, 0.01 = 1%. If the OVERRIDE_LIMITS variable is TRUE, the limits can be specified manually with the X_LOW and X_HIGH variables, which can be set from the Plot menu.

This function should only be used on data with a single sweep variable. A 3 point data set, containing slope and intercept data and the regression coefficient, is returned.

Input Arguments:

Data Sets:	X Data, Y Data
Reals or Integers:	RMS limit, Buffer
Output:	Array of 2 points: slope then intercept
Automatic Invocation:	None

Example PEL Statement:

```
fit_data = autofit(-ve,log(ic.m),0.01,0.1)
```

B2200_bias_card_enable Bias-enables all the output ports of the specified card. By default, all ports are bias-enabled after a reset.

Syntax

```
B2200_bias_card_enable(<addr>, <CardNumber>, <CardState>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<CardState> is the card output port's state (allowed values are "ENABLE", "DISABLE", "E", or "D").

B2200_bias_ch_enable Bias-enables specific output ports in the channel list for the specified card. The input ports specified in the channel list are ignored since the input port is always the Bias Input Port. By default, all the outputs are bias-enabled after a reset.

Syntax

```
B2200_bias_ch_enable(<addr>,<CardNumber>,<State>,
<Channel list>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<State> is the output port's state (allowed values are "ENABLE", "DISABLE", "E", or "D")

<Channel list> is the list of channels, known as connection routes. Example channel list: (@10102, 10203, 10305:10307)

B2200_bias_enable Enables the bias mode for the specified card once Input Bias Port and Enabled Output ports are specified. When Bias Mode is ON, the Input Bias Port is connected to all Bias Enabled output ports that are not

connected to any other input ports. Bias Disabled output ports are never connected to an Input Bias Port when Bias Mode is ON.

If another input port is disconnected from a bias enabled output port, this port is automatically connected to the Input Bias Port.

If another input port is connected to a Bias Enabled output port, the output port is automatically disconnected from the Bias Input Port. When Bias Mode is OFF, the Input Bias Port is the same as the other ports.

Syntax

```
B2200_bias_enable(<addr>, <CardNumber>, <mode>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<mode> is "On", "Off", "1", or "0".

B2200_bias_init Selects the Input Bias Port for the specified card. The Input Bias Port is the dedicated bias port.

Syntax

```
B2200_bias_init(<addr>, <CardNumber>, <InputBiasPort>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<InputBiasPort> is 1 to 14 (numeric input) or –1 to disable bias port.

B2200_close_interface Closes the current interface, which was opened by calling B2200_open_interface().

B2200_connect Connects or disconnects specified channels. Bias Mode and coupling Mode are also taken into account when a channel is closed or opened.

For example, in the list (@10102, 10203:10205), the following channels are connected or disconnected on card 1. Input port 1 to output port 2. Input port 2 to output port 3 and 5.

Syntax

```
B2200_connect(<addr>,<Connect/Disconnect>,<ChannelList>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<Connect/Disconnect> is C or D.

<ChannelList> is the list of connections to close.

B2200_couple_enable Enables or disables Couple Port mode. Couple Port mode allows synchronized connection of two adjacent input ports to two adjacent output ports.

Syntax

```
B2200_couple_enable(<addr>, <CardNumber>, <Mode>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<mode> is "On", "Off", "1", or "0".

B2200_couple_setup Selects the couple ports for Kelvin connections. At Reset, no input ports are coupled.

Syntax

```
B2200_couple_setup( <addr>,<CardNumber>,
<ListOfCoupledPorts>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<ListOfCoupledPorts> is the list of odd number input channels (e.g., "1, 3, 5" means coupled ports are 1-2, 3-4, 5-6).

B2200_debug Prints out all command strings sent to the instrument when set to 1. This flag is common to all B2200A's on the bus, regardless of their GPIB address.

Syntax

```
B2200_debug(<flag>)
```

Where

<flag> is "1", "0", "Yes", or "No".

B2200_disconnect_card Opens all relays or channels in the specified cards.

Syntax

```
B2200_disconnect_card(<addr>, <CardNumber>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

B2200_GPIB_handler Returns -1 if the interface has not been initialized (invalid handler). Returns a positive integer (handler) if the interface has been opened.

Returns the current interface handler. The function is provided as a utility function, which enables you to write advanced PEL code to write and read data to the B2200A using the HPIB_write and HPIB_read functions. Initializing the handler using B2200_open_interface enables you to use B2200A's built-in driver functions as well as writing PEL code to support other features that are not currently supported by the built-in functions, all in the same PEL code.

B2200_ground_card_enable Enables ground-enabling for all the output ports of the specified card. By default, all ports are ground-disabled.

Syntax

```
B2200_ground_card_enable(<addr>,<CardNumber>,<CardState>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<CardState> is the card output port's state (allowed values are "ENABLE", "DISABLE", "E", or "D").

B2200_ground_enable Enables the bias mode for the specified card. When Ground Mode is turned ON, the Input Ground Port (default is 12) is connected to all the Ground Enabled input/output ports that have not been connected to any other port. At Reset, Ground Mode is OFF. Ground Mode cannot be turned ON when Bias Mode is ON.

See the Agilent B2200 *User's Guide* for additional comments and restrictions.

Syntax

```
B2200_ground_enable(<addr>, <CardNumber>, <mode>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, 4.

<mode> is "On", "Off", "1", or "0".

B2200_ground_init Selects the input Ground Port for the specified card. For each card, you can specify the same or a different Ground Port. By default, the input Ground Port is port 12. The ground port should be connected to 0 V output voltage. See the Agilent B2200 *User's Guide* for details.

Syntax

```
B2200_ground_init(<addr>,<CardNumber>,<InputGroundPort>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<InputGroundPort> is 1 to 14 (numeric input) or –1 to disable ground port.

B2200_ground _outch_enable Ground-enables or ground-disables output ports. When Ground Mode is turned ON, the ground-enabled output ports that have not been connected to any other input port are connected to the input ground port. The input ports specified in channel lists are ignored since the input port is always the Input Ground Port. By default, all the outputs are ground-disabled after a reset.

Syntax

```
B2200_ground _outch_enable(<addr>,<CardNumber>,<State>,
<Channel list>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, or 4.

<State> is the port's state (allowed values are "ENABLE", "DISABLE", "E", or "D").

<Channel list> is the list of channels, known as connection routes. Example channel list: (@10102, 10203, 10305:10307)

B2200_ground _unused_inputs Specifies the ground-enabled (or unused) input ports for the specified card. When Ground Mode is turned ON, the ground-enabled input ports that have not been connected to any other port are connected to the input Ground Port. By default, all the inputs are ground-disabled after a reset.

Syntax

```
B2200_ground _unused_inputs(<addr>,<CardNumber>,<Input
Channels>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<CardNumber> is 0(auto), 1, 2, 3, 4.

<Input Channels> is the list of input channels (e.g., "1, 2, 5"). Only input ports 1 to 8 can be defined as unused (these are the input Kelvin Ports).

B2200_init Must be run first in the PEL program to initialize the instrument and set the configuration mode. When the instrument is in AUTO configuration mode and multiple plug-in cards are installed in the B2200 slots from slot 1 continuously, the installed cards are then treated as one card (numbered 0). This function resets all the settings to factory default before setting the configuration mode.

This function also sets the default connection rule for the specified card. When the connection rule is FREE (default mode), each input port can be connected to multiple output ports and each output port can be connected to multiple input ports. When the connection is SINGLE, each input port can be connected to only one output. Connection sequence specifies the open/close sequence of the relays when changing from an existing connection to a new connection.

Syntax

```
B2200_init( <addr>, <cardNumber>, <config>,
<connectionRule>, <connectionSequence>)
```

Where

<addr> is the GPIB address of the Mainframe (must be a positive number from 1 to 30).

<cardNumber> is 0(auto), 1, 2, 3, or 4.

<config> is "AUTO" or "NORMAL" (string input).

<connectionRule> is "FREE" or "SINGLE".

<connectionSequence> is "NSEQ", "BBM", or "MBBR".

- NSEQ (No SEQuence): Disconnect old route, connect new route.
- BBM (Break Before Make): Disconnect old route, wait, connect new route.
- MBBR (Make Before BReak): Connect new route, wait, disconnect old route.

B2200_open_interface Opens and initializes the GPIB interface and must be run first in the PEL program. The interface handler is saved in a static variable so that the interface will be shared by all the other B2200's function calls. You can drive multiple B2200 instruments as long as they are on the same interface bus (obviously, they must have different addresses).

Syntax

```
B2200_open_interface(<Interface Name>)
```

Where

<Interface Name> is the name of the GPIB interface.

BJT_dc_model Calculates collector current (IC), base current (IB) or gain (BETA) versus terminal voltages for a bipolar transistor using the UCB DC bipolar model. Set the *Output* field to IC, IB, or BETA. Use this function in place of an actual simulation for fast optimizations. The source code for this function is provided as an example in the *userc.c* file.

Input Arguments:

Data Sets:	VC, VB, VE
Strings/Pars/Vars	Output
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

BJTAC_high_freq Standard extraction for the UCB Bipolar model. Extracts AC parameters from a common emitter measurement of H-parameters. Requires the following setup:

H versus V_{be}, with V_{ce} = 1V and 3V, and Freq constant.

The frequency value must be past the pole frequency of the device. Optimization can be used to tune the parameter values; typically, it should not be required.

Input Arguments:

Data Sets:	Base Voltage, Frequency, Col Voltage, Sub Voltage, H-Par Output
Output:	None
Extracts:	TF, ITF, XTF, VTF, PTF
Automatic Invocation:	By Extract menu function

BJTAC_rb_rbm_irb Standard extraction for the UCB Bipolar model. Extracts base resistance parameters from a common emitter measurement of H_{11}. Requires the following setups:

I_b versus V_{be}, with V_{ce} = constant
H_{11} versus Freq versus V_{be}, with V_{ce} = constant

Input Arguments:

Data Sets:	IB Data, RBB Data
Output:	None
Extracts:	RB, RBM, IRB
Automatic Invocation:	By Extract menu function

BJTCV_stoc Calculates capacitance data from S-parameter data using the following equations:

Cbc(Vbc) = – imag(Y12)/(2*pi*freq)

Cbe(Vbe) = imag(Y11)/(2*pi*freq) - Cbc(Vbc)

This allows base-collector and base-emitter capacitance to be calculated from network analyzer measurements. The output of this function can be used in place of actual capacitance data to extract capacitance related parameters.

Input Arguments:	
Data Sets:	FREQ data, S data
Strings/Pars/Vars:	Node (C/E)
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

BJTDC_fwd_gummel Standard extraction for the UCB Bipolar model. Extracts forward Gummel parameters from forward Gummel plot measurements. Requires the following setup:

I_c and I_b versus V_{be}, with V_{cb} = 0V.

The measured data should include high and low current roll-off effects in the gain. The V_{be} lower limit for extraction is automatically selected. If the *OVERRIDE_LIMITS* variable is true, this limit can be specified manually with the *X_LOW* variable, which can be set from the *Plot* menu. Optimization can be used to tune the parameter values, but should not typically be required.

Input Arguments:	
Data Sets:	Fwd VBE, Fwd IC, Fwd IB, Fwd Beta
Output:	None
Extracts:	ISE, NE, BF, IKF
Automatic Invocation:	By Extract menu function

BJTDC_is_nf Standard extraction for the UCB Bipolar model. Extracts saturation current parameters from forward gummel plot measurements. Requires the following setup:

I_c and I_b versus V_{be}, with V_{cb} = 0V.

The V_{be} limits for extraction are automatically selected. If the *OVERRIDE_LIMITS* variable is true, these limits can be specified manually with the *X_LOW* and *X_HIGH* variables, which can be set from the *Plot* menu. Optimization can be used to tune the parameter values, but should not typically be required.

Input Arguments:	
Data Sets:	Fwd VBE, Log10 Fwd IC
Output:	None
Extracts:	IS, NF
Automatic Invocation:	By Extract menu function

BJTDC_nr Standard extraction for the UCB Bipolar model. Extracts NR from reverse Gummel Plot measurements. Requires the following setup:

I_e and I_b versus V_{bc}, with V_{eb} = 0V.

The Vbc limits for extraction are automatically selected. If the *OVERRIDE_LIMITS* variable is true, these limits can be specified manually with the *X_LOW* and *X_HIGH* variables, which can be set from the *Plot* menu. Optimization can be used to tune the parameter value, but should not typically be required.

Input Arguments:	
Data Sets:	Rev VBC, Log10 Rev IE
Output:	None
Extracts:	NR
Automatic Invocation:	By Extract menu function

BJTDC_rc Standard extraction for the UCB Bipolar model. Extracts collector resistance in the saturation region. Requires the following setup:

I_c versus V_{ce}, with V_{be} = typical operating value.

Depending on the device, optimization to this and other DC measurements may be required to tune the parameter value.

Input Arguments:

Data Sets:	VC Data, IC Data
Output:	None
Extracts:	RC
Automatic Invocation:	By Extract menu function

BJTDC_rcfb Alternate extraction for the UCB Bipolar model. Extracts collector resistance using the flyback technique. Requires the following setup:

V_{ec} versus I_b, with the emitter floating.

Depending on the device, optimization to this and other DC measurements may be required to tune the parameter value.

Input Arguments:

Data Sets:	IB Data, VE Data
Output:	None
Extracts:	RC
Automatic Invocation:	By Extract menu function

BJTDC_re Standard extraction for the UCB Bipolar model. Extracts emitter resistance using the flyback technique. Requires the following setup:

V_{ce} versus I_b, with the collector floating.

Depending on the device, optimization to this and other DC measurements may be required to tune the parameter value.

Input Arguments:

Data Sets:	IB Data, VC Data

Output:	None
Extracts:	RE
Automatic Invocation:	By Extract menu function

BJTDC_rev_gummel Standard extraction for the UCB Bipolar model. Extracts reverse Gummel parameters from reverse Gummel plot measurements. Requires the following setup:

I_e and I_b versus V_{bc}, with V_{eb} = 0V.

The measured data should include high and low current roll-off effects in the gain. The Vbc lower limit for extraction is automatically selected. If the *OVERRIDE_LIMITS* variable is true, this limit can be specified manually with the *X_LOW* variable, which can be set from the *Plot* menu. Optimization can be used to tune the parameter values, but should not typically be required.

Input Arguments:	
Data Sets:	Rev VBC, Rev IE, Rev IB, Rev Beta
Output:	None
Extracts:	ISC, NC, BR, IKR
Automatic Invocation:	By Extract menu function

BJTDC_vaf_var Standard extraction for the UCB Bipolar model. Extracts forward and reverse early voltages from common emitter and common collector curves. Requires the following setups:

I_c versus V_{ce} versus V_{be}.
I_e versus V_{ec} versus V_{bc}.

The setups should have the same number of base voltage steps. The base voltages should be chosen so that current levels correspond to the peak gain regions of the device. No more than 20 percent of the data should be in the saturation region. Optimization can be used to tune the parameter

values, but should not typically be required. Optimization of these parameters should be performed only after extracting the complete DC model.

Input Arguments:

Data Sets:	Forward VC, Forward VB, Forward IC, Reverse VE, Reverse VB, Reverse IE
Output:	None
Extracts:	VAF, VAR
Automatic Invocation:	By Extract menu function

BPOPAMP_macro_model Extraction function for the Boyle-Pederson- Solomon-Cohn Opamp macromodel written in C code. (Refer to IEEE JSSC vol. SC-9, no. 6, Dec. 1974.) Extracts circuit element values for a specified set of opamp performance measurements. The data set inputs to the extraction function may be from outputs of Setups that measure the specific opamp performance or from values known via other sources such as specifications on a data sheet. The real and integer inputs are not generally measurable and are taken from the knowledge of the design of the opamp being modeled. An expanded description of the inputs is given in parentheses where applicable.

Input Arguments:

Data Sets:	Slew Rate +(V/uS), Slew Rate -(V/uS), Bias Current(Amps), Bias Offset(Amps), Volt Offset(Volts), Av(DM) (gain-no unit), BW(Hz), Excess Phase(radians), CMRR (dB), Rout(ohms), Rout-ac(ohms), Isc +(Amps), Isc -(Amps), Vout_max +(Volts), Vout_min -(Volts), Power Diss(Watts), Vcc supply(Volts), Vee supply(Volts)

Reals or Integers:	Nom. Q.IS(nominal input transistor saturation current), R2(mid-stage gain setting resistor), Comp. Cap.(compensation capacitance), Temp.(C), Inputs PNP?(=1 if input stage uses pnps), Debug?(=1 print debug information during extraction)
Output:	None
Extracts:	NPN1.BF, NPN1.IS, NPN2.BF, NPN2.IS, C1, RC1, RC2, RE1, RE2, RE, CE, RP, GCM, GA, R2, C2, GB, RO2, RC, RO1, DMOD1.IS, DMOD2.IS, VC, VE, IEE
Automatic Invocation:	By Extract menu function

BSIM1DC_geom_indep This function is obsolete.

Generates the BSIM geometry independent parameters (all parameters scaled to channel length and width) from a device file generated either by the BSIM extraction routines in IC-CAP or from a compatible BSIM characterization system.

Input Arguments:	None
Output:	None

Extracts:	VFB, LVFB, WVFB, PHI, LPHI, WPHI, K1, LK1, WK1, K2, LK2, WK2, ETA, LETA, WETA, MUZ, U1, LU1, WU1, DL, DW, X2E, LX2E, WX2E, X3D, LX3E, WX3E, X2MZ, LX2MZ, WX2MZ, MUS, LMUS, WMUS, X2MS, LX2MS, WX2MS, X3MS, LX3MS, WX3MS, X2U0, LX2U0, WX2U0, X2U1, LX2U1, WX2U1, X3U1, LX3U1, WX3U1 If subthreshold parameters are extracted, the following geometry independent parameters are also extracted: N0, LN0, WN0, NB, LNB, WNB, ND, LND, WND
Automatic Invocation:	By Extract menu function

BSIM1DC_lin_sat This function is obsolete.

Extracts the linear and saturation region parameters of the BSIM model using Id versus Vg curves for a single device.

Input Arguments:	
Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	The linear region parameters: VFB, PHI, K1, K2, U0, X2U0. The saturation region parameters: ETA, MUZ, U1, X2MZ, X2E, X3E, X2U1, MUS, X2MS, X3MS, X3U1.
Automatic Invocation:	By Extract menu function

BSIM1DC_sub This function is obsolete.

Extracts the BSIM subthreshold parameters for a single device using 4 I_d versus V_g curves.

Input Arguments:	
Data Sets:	Gate V, Bulk V, Drain V, Drain I 1, Drain I 2, Drain I 3, Drain I 4
Output:	None
Extracts:	N0, NB, ND
Automatic Invocation:	By Extract menu function

BSIM2_lin_plot This function is obsolete.

Acquires specified parameter value data versus 1/W or 1/L and displays plot.

Input Arguments:	
Data Sets:	Input an output data set with both measured and simulated data types set
Strings/Pars/Vars:	Parameter name of parameter to be plotted against 1/W or 1/L, Sort Key - W or L
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

BSIM2_save_dev_pars This function is obsolete.

Appends the set of BSIM2 extracted parameters for a single device to the device file in the user's home directory.

Input Arguments:	None
Output:	None
Automatic Invocation:	By Extract menu function

BSIM2DC_geom_indep This function is obsolete.

Generates the BSIM2 geometry independent parameters (all parameters scaled to channel length and width) from a device file generated by the BSIM2 extraction routines in IC-CAP or from a compatible BSIM2 characterization system.

Input Arguments:	None
Output:	None
Extracts:	VFB, LVFB, WVFB, PHI, LPHI, WPHI, K1, LK1, WK1, K2, LK2, WK2, ETA0, LETA0, WETA0, MU0, DL, DW, UA0, LUA0, WUA0, U10, LU10, WU10, MU0B, LMU0B, WMU0B, ETAB, LETAB, WETAB, UB0, LUB0, WUB0, UAB, LUAB, WUAB, U1B, LU1B, WU1B, MUS0, LMUS0, WMUS0, MUSB, LMUSB, WMUSB, UBB, LUBB, WUBB, U1D, LU1D, WU1D, N0, LN0, WN0, NB, LNB, WNB, ND, LND, WND, MU20, LMU20, WMU20,MU2B, LMU2B, WMU2B, MU2G, LMU2G, WMU2G, MU30, LMU30, WMU30, MU3B, LMU3B, WMU3B, MU3G, LMU3G, WMU3G, MU40, LMU40, WMU40, MU4B, LMU4B, WMU4B, MU4G, LMU4G, WMU4G, VOF0, LVOF0, WVOF0, VOFB, LVOFB, WVOFB, VOFD, LVOFD, WVOFD, AI0, LAI0, WAI0, AIB, LAIB, WAIB, BI0, LBI0, WBI0, BIB, LBIB, WBIB, VGHIGH, LVGHIGH, WVGHIGH, VGLOW, LVGLOW, WVGLOW
Automatic Invocation:	By Extract menu function

BSIM2DC_lin_sat This function is obsolete.

Extracts the linear, saturation, and subthreshold region parameters of the BSIM2 model using 2 families of I_d versus V_g curves for a single device. Also extracts the output resistance parameters of the BSIM2 model using 2 families of I_d versus V_d curves for a single device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I vs Vg, Drain I vs Vd
Output:	None
Extracts:	The linear region parameters: VFB, PHI, K1, K2, MU0, MU0B, UA0, UAB, UB0, UBB, VGHIGH, VGLOW. The saturation region parameters: MUS0, MUSB, U10, U1B, ETA0, ETAB, VOF0, VOFD, VOFB. The subthreshold region parameters: N0, NB, ND. The output resistance parameters: MU20, MU2B, MU2G, MU30, MU3B, MU3G, MU40, MU4B, MU4G, AI0, AIB, BI0, BIB, U1D
Automatic Invocation:	By Extract menu function

BSIM3_calculate Calculates the drain current of the BSIM3v3.2 model and different internal states of the model for the given terminal voltages vd, vg, vs, and vb. The type of internal state, for example, the drain source resistance rds can be selected by the select output flag. In some cases it is necessary to use a measured value for the threshold voltage instead of the calculated. Use the select input flag to select measured or calculated. If this is not equal to zero, then the value in value input is used for vth instead of the calculated one.

Input Arguments:

Variables:	vd Drain voltage vg Gate voltage vs Source voltage vb Bulk voltage Length (L) Gate length Width (W) Gate width select input (if 1 use value input for Vth) value input (value input for Vth if select input = 1)
Parameters:	None

Output:	Value to calculate or failure indicator
	output[0] = lx;
	output[1] = wx;
	output[2] = vbseff;
	output[3] = vt0;
	output[4] = nonlat;
	output[5] = dvtx;
	output[6] = dvtx_w;
	output[7] = k3w0;
	output[8] = eta_vd;
	output[9] = vth;
	output[10] = vgsteff;
	output[11] = abulk;
	output[12] = ueff;
	output[13] = rds;
	output[14] = vdsat;
	output[15] = vdseff;
	output[16] = idlin;
	output[17] = idr;
	output[18] = vasat;
	output[19] = vaclm;
	output[20] = vadiblc;
	output[21] = inv_vascbe;
	output[22] = va;
	output[23] = idout;

Extracts:	Nothing

BSIM3_check_par Checks whether a model parameter is in a predefined range. The range information for this parameter must be given in a variable in the referenced path. The range information is stored in a string in the following format:

```
range_A0
>-1  0   10  -
  |  |    |  |___ upper error condition ({operator(<,<=), value}{-)}
  |  |    |______ upper optimization boundary
  |  |___________ lower optimization boundary
  |______________ lower error condition ({operator(>,>=), value}{-)}
```

Input Arguments:

Variables:	Actual value of parameter to check
Parameters:	Parameter name Path to parameter range definition
Output:	Flag for correct operation: 0: parameter is in specified range –1: parameter is outside specified range –2: error during function execution (e.g., variable 'range_xx' not found)

Example call in PEL:

```
check = BSIM3_check_par(prwg,"PRWG",
      "/BSIM3_DC_CV/Extraction_configuration/Boundaries")
```

BSIM3_DC_calc_bin_parameter This function calculates from the input the 4 binning parameters P0, PL, PW, and PP. If the calculation is done correctly, outputs[0] will return 0. Otherwise, outputs[0] will result in a negative number. In such a case, the error will be printed in detail in the output window.

Input Arguments:

Inputs:	Array with 4 parameters P1 .. P4 of the bin corners Array with 4 gate lengths L1 .. L4 of the bin corners Array with 4 gate widths W1 .. W4 of the bin corners Array with 4 values for the number of gate fingers NF1 .. NF4 of the bin corners Parameter set (get with 'BSIM3_DC_get_parameter()')
Output:	Array containing error condition and binning parameters outputs[0] = error condition (0=o.k., any other number indicates an error) outputs[1] = P0 outputs[2] = PL outputs[3] = PW outputs[4] = PP
Extracts:	Binning parameters P0, PL, PW, PP

Example call in PEL:

```
complex l[4]
complex w[4]
:
l[0]= 1u
:
par     = BSIM3_DC_get_parameter()
bin_par = BSIM3_DC_calc_bin_parameter(p, l, w, par)
```

BSIM3_DC_calculate Calculates the drain current of the BSIM3v3.2 model and different internal states of the model for the given terminal voltages vd, vg, vs, and vb. The type of internal state, for example, the drain source resistance rds can be selected by the select output flag. In some cases, it is necessary to use a measured value for the threshold voltage instead of the calculated. Use the select input flag to select

measured or calculated. If this is not equal to zero, then the value in value input is used for vth instead of the calculated one.

Input Arguments:

Variables:	vd Drain voltage vg Gate voltage vs Source voltage vb Bulk voltage Length (L) Gate length Width (W) Gate width select input (if 1 use value input for Vth) value input (value input for Vth if select input = 1)

Output:

Vector with BSIM4 internal states for the given DC bias point.
By setting debug = 1, this vector is printed with explanations:

0. leff
1. weff
2. -
3. -
4. dl
5. dws
6. vtm0
7. eg0
8. ni
9. vbi
10. vbc
11. xdep0
12. xdep
13. cdep
14. cox
15. -
16. -
17. lt0
18. lt
19. ltw
20. phi
21. phis
22. VFB
23. -

24. vgsteff
25. vbseff
26. vdseff
27. vth0
28. -
29. -
30. pocket implant =nonlat
31. narrow channel effect = k3w0
32. short channel effect = dvtx
33. small channel effect = dvtx_w
34. high vds effect = eta_vd
35. vth
36. -
37. abulk
38. litl
39. ueff
40. esat
41. rds
42. -
43. -
44. vdsat
45. ids0 (without resistance)
46. idsr (with resistance)
47. vasat
48. vaclm
49. va
50. -
51. -
52. vadibl
53. inv_vascbe
54. ids (with output resistance)
55. -
56. n
57. -
58. actual version

Example call in PEL:

```
erg = BSIM3_DC_calculate(par, point_vd, point_vg, 0,
   point_vb, MAIN.L, MAIN.W, 0, 0, TEMP, TYPE, 0)
```

BSIM3_DC_get_parameter This function loads all BSIM3 model parameters from the actual model parameter set and checks them for consistency. Without finding errors, the function gives back an array with model parameters in a given order.

Output: Array of BSIM3 model parameters in the following order:

```
error = outputs[0]; ! in case of an
  ! error during the parameter
check
  ! error would be set to 1e-99
LEVEL = outputs[1];
VERSION = outputs[2];
MOBMOD = outputs[3];
TOX = outputs[4]
TOXM = outputs[5]
XJ = outputs[6]
NCH = outputs[7]
NGATE = outputs[8]
RSH = outputs[9]
VTH0 = outputs[10]
K1 = outputs[11]
K2 = outputs[12]
K3 = outputs[13]
K3B = outputs[14]
W0 = outputs[15]
NLX = outputs[16]
VBM = outputs[17]
DVT0 = outputs[18]
DVT1 = outputs[19]
DVT2 = outputs[20]
DVT0W = outputs[21]
DVT1W = outputs[22]
DVT2W = outputs[23]
U0 = outputs[24]
UA = outputs[25]
UB = outputs[26]
UC = outputs[27]
VSAT = outputs[28]
```

A0 = outputs[29]
AGS = outputs[30]
B0 = outputs[31]
B1 = outputs[32]
KETA = outputs[33]
A1 = outputs[34]
A2 = outputs[35]
WINT = outputs[36]
LINT = outputs[37]
DWG = outputs[38]
DWB = outputs[39]
VOFF = outputs[40]
NFACTOR = outputs[41]
ETA0 = outputs[42]
ETAB = outputs[43]
DSUB = outputs[44]
CIT = outputs[45]
CDSC = outputs[46]
CDSCB = outputs[47]
CDSCD = outputs[48]
PCLM = outputs[49]
PDIBLC1 = outputs[50]
PDIBLC2 = outputs[51]
PDIBLCB = outputs[52]
DROUT = outputs[53]
PSCBE1 = outputs[54]
PSCBE2 = outputs[55]
PVAG = outputs[56]
DELTA = outputs[57]
RDSW = outputs[58]
PRWG = outputs[59]
PRWB = outputs[60]
WR = outputs[61]
ALPHA0 = outputs[62]
ALPHA1 = outputs[63]
BETA0 = outputs[64]
TNOM = outputs[65]
UTE = outputs[66]
KT1 = outputs[67]
KT1L = outputs[68]
KT2 = outputs[69]

UA1 = outputs[70]
UB1 = outputs[71]
UC1 = outputs[72]
AT = outputs[73]
PRT = outputs[74]
WL = outputs[75]
WLN = outputs[76]
WW = outputs[77]
WWN = outputs[78]
WWL = outputs[79]
LL = outputs[80]
LLN = outputs[81]
LW = outputs[82]
LWN = outputs[83]
LWL = outputs[84]
WLC = outputs[85]
WWC = outputs[86]
WWLC = outputs[87]
BINUNIT = outputs[88]

Example call in PEL:

```
par = BSIM3_DC_get_parameter()
```

BSIM3_DC_vth Picks up 1 single sweep curve of id=f(vg) of a specified setup and extracts the threshold voltage vth. The setup is specified by the parameters path to vd, ... etc. This makes it easier to call the function with variable inputs inside the PEL programs.

The 'Flag' variable is used to define certain conditions, for example, the extraction of vth for the large device that does not need to calculate all the early voltage values.

Input Arguments:

Input:	parameter set (get with 'BSIM3_DC_get_parameter()')

Variables:	Length (L) Width (W) Flag for extraction options flag: 0 Large device @ low vds 1 Short and small device @ low vds 2 Short and small device @ high vds 3 A constant reference current Idref = ID_REF_VTH*W/L is used where ID_REF_VTH is a model variable. # of curve Temperature (Degree C) Type (1=NMOS, -1=PMOS) Debug (1: show internal states of the function 0:)
Parameters:	path to setup vd vg vb id type id
Output:	Value vth or failure indicator
Extracts:	Vth (1e99 indicates error)

Example call in PEL:

```
erg = BSIM3_DC_vth(par, MAIN.L, MAIN.W, flag, i,
       TEMP, TYPE, 0, ".", "vd","vg","vb","id","M")
```

BSIM3_error This function takes a set of measured and simulated data and calculates the error between simulation and measurement in the specified range (xmin, xmax, ymin, ymax). The error is given back as output. In addition, the maximum error and the root mean square (RMS) error are given back through an IC-CAP system variable.

Input Arguments:

Inputs:	x-coordinate values measured y-coordinate values simulated y-coordinate values
Variables:	x_min x_max y_min y_max
Parameters:	IC-CAP Variable to write MAX_ERROR IC-CAP Variable to write RMS_ERROR
Output:	error in the specified range, all other points of the output = 0

Example call in PEL:

```
error = BSIM3_error(vg,id.m,id.s,0,3,0,1e-6,"MAX_ERROR",
"RMS_ERROR")
```

BSIM3_set_opt The function accepts a list of model parameters, separated by blanks (e.g., “A0 AGS KETA”) and searches the range information for these parameters in the *range_<PARAMETER>* variables in the referenced path.

After analyzing the range information for each parameter, the variables *min_<PARAMETER>* and *max_<PARAMETER>* in the local setup/DUT are set. These variables can be used as upper/lower limit in an optimizer call.

The range information is stored in a string in the following format:

```
range_A0
>-1  0   10  -
  |  |    |  |___ upper error condition ({operator(<,<=), value}{-)}
  |  |    |______ upper optimization boundary
  |  |___________ lower optimization boundary
  |______________ lower error condition ({operator(>,>=), value}{-)}
```

Input Arguments:

Parameters:	Parameter names, separated by blanks Path to parameter range definition
Output:	Flag for correct operation: 0: everything is ok -1: error during function execution (e.g., variable 'range_xx' not found)

Example call in PEL:

```
erg = BSIM3_set_opt("RDSW PRWG
       PRWB","Extraction_configuration/Boundaries")
```

BSIM3_toolkit_vth Picks up 1 single sweep curve of id=f(vg) of a specified setup and extracts the threshold voltage vth. The setup is specified by the parameters path to vd and so on. This makes it easier to call the function with variable inputs inside the PEL programs.

The *Flag* variable is used to define certain conditions. For example, the extraction of vth for the large device, which does not need to calculate all the early voltage values.

Input arguments

Variables:	Length (L) Width (W) Flag for extraction options flag: 0 Large device q low vds 1 Short and small device @ low vds 2 Short and small device @ high vds # of curve
Parameters:	path to setup, vd, vg, vb, id, type id

Output:	Value vth or failure indicator
Extracts:	Vth (1e99 indicates error)

BSIM3CV_total_cap Extracts the total PN junction capacitance parameters from the bottom and sidewall for the BSIM3 model. Requires C-V measurement on 2 different geometries. The first measurement should be on a device in which the bottom capacitance dominates. The second measurement should be on a device in which the sidewall capacitance dominates.

Extracts:	CJ, MJ, CJSW, MJSW, PB

BSIM3CVmodCBD BSIM3 Bulk to Drain Capacitance model. Calculates CBD from the input voltage.

BSIM3CVmodCBS BSIM3 Bulk to Source Capacitance model. Calculates CBS from the input voltage.

BSIM3DC_bulk_short Standard extraction for the BSIM 3 model. Extracts substrate current parameters using Ib versus Vg measured on a set of devices with a large and fixed width and different length.

Extracts:	ALPHA0, BETA0

BSIM3DC_lin_large Standard extraction for the BSIM 3 model. Extracts linear region parameters using Id versus V_g measured on a large device.

Extracts:	VTH0, K1, K2, U0, UA, UB, UC, VOFF

BSIM3DC_lin_narrow Standard extraction for the BSIM 3 model. Extracts width effect parameters using Id versus V_g measured on a set of devices with a large and fixed length and different width.

Extracts: K3, W0, K3B, WINT, DWB

BSIM3DC_lin_short Standard extraction for the BSIM 3 model. Extracts length effect parameters using I_d versus V_g measured on a set of devices with a large and fixed width and different length.

Extracts: DVT0, DVT1, DVT2, LINT, RDSW, NLX, PRWB

BSIM3DC_lin_small Standard extraction for the BSIM 3 model. Extracts small effect parameters using Id versus Vg measured on a set of devices with a short and fixed length and different width.

Extracts: WR, DVT0W, DVT1W, DVT2W

BSIM3DC_model UCB BSIM3 MOS model. Calculates Id, Gd, Rout, or Ib from voltages.

BSIM3DC_sat_narrow Standard extraction for the BSIM 3 model. Extracts saturation parameters using Id versus Vd measured on a set of devices with a large and fixed length and different width.

Extracts: B0, B1

BSIM3DC_sat_short Standard extraction for the BSIM 3 model. Extracts saturation and output resistance parameters using Id versus Vd measured on a set of devices with a large and fixed width and different length.

Extracts: A0, A1, A2, DROUT, VSAT, PCLM, PDIBLC1, PDIBLC2, PSCBE1, PSCBE2, PVAG

BSIM3DC_sat_short2 Standard extraction for the BSIM 3 model. Extracts saturation parameters using Id versus Vd measured on a set of devices with a large and fixed width and different length.

Extracts: KETA, PDIBLCB

BSIM3DC_sub_short Standard extraction for the BSIM 3 model. Extracts subthreshold parameters using Id versus Vg measured on a set of devices with a large and fixed width and different length.

Extracts: CDSC, CDSCB, NFACTOR

BSIM3DC_sub_short2 Standard extraction for the BSIM 3 model. Extracts subthreshold parameters at high drain voltage using Id versus Vg measured on a set of devices with a large and fixed width and different length.

Extracts: ETA0, ETAB, CDSCD

BSIM3DC_vth Calculates the threshold voltage from Id versus Vg measurements.

BSIM3DC_vth_sim Calculates the threshold voltage from the model parameters.

BSIM3DC_vth_versus Acquires threshold voltage data versus length or width to display in plot.

BSIM4_check_par Checks whether a model parameter is in a predefined range. The range information for this parameter must be given in a variable in the referenced path. The range information is stored in a string in the following format:

```
range_A0
>-1  0   10  -
  |  |    |  |___ upper error condition ({operator(<,<=), value}{-)}
  |  |    |______ upper optimization boundary
  |  |___________ lower optimization boundary
  |______________ lower error condition ({operator(>,>=), value}{-)}
```

Input Arguments:

Variables:	Actual value of parameter to check
Parameters:	Parameter name Path to parameter range definition
Output:	Flag for correct operation: 0: parameter is in specified range –1: parameter is outside specified range –2: error during function execution (e.g. variable 'range_xx' not found)

Example call in PEL:

```
check = BSIM4_check_par(prwg,"PRWG",
      "/BSIM4_DC_CV/Extraction_configuration/Boundaries")
```

BSIM4_DC_calc_bin_parameter This function calculates from the input the 4 binning parameters P0, PL, PW, and PP. If the calculation is done correctly, outputs[0] will return 0. Otherwise, outputs[0] will result in a negative number. In such a case, the error will be printed in detail in the output window.

Input Arguments:

Inputs:	Array with 4 parameters P1 .. P4 of the bin corners Array with 4 gate lengths L1 .. L4 of the bin corners Array with 4 gate widths W1 .. W4 of the bin corners Array with 4 values for the number of gate fingers NF1 .. NF4 of the bin corners Parameter set (get with 'BSIM4_DC_get_parameter()')
Output:	Array containing error condition and binning parameters outputs[0] = error condition (0=o.k., any other number indicates an error) outputs[1] = P0 outputs[2] = PL outputs[3] = PW outputs[4] = PP
Extracts:	Binning parameters P0, PL, PW, PW

Example call in PEL:

```
complex l[4]
complex w[4]
:
l[0]= 1u
:
par     = BSIM4_DC_get_parameter()
bin_par = BSIM4_DC_calc_bin_parameter(p, l, w, nf, par)
```

BSIM4_DC_calculate Calculates the drain current of the BSIM4.2.0 model and different internal states of the model for the given terminal voltages vd, vg, vs, and vb. The type of internal state, for example, the drain source resistance rds can be selected by the select output flag. In some cases, it is necessary to use a measured value for the threshold voltage instead of the calculated. Use the select input flag to select measured or calculated. If this is not equal to zero, then the value in value input is used for vth instead of the calculated one.

Input Arguments:

Input:	Parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	vd Drain voltage vg Gate voltage vs Source voltage vb Bulk voltage Length (L) Gate length Width (W) Gate width Number fingers (NF) Number of gate fingers select input (if 1 use value input for Vth) value input (value input for Vth if select input = 1)

Output:

Vector with BSIM4 internal states for the given DC bias point.
By setting debug = 1, this vector is printed with explanations:

0. leff
1. weff
2. weffs
3. weffcj
4. dl
5. dws
6. vtm0
7. eg0
8. ni
9. vbi
10. vbc
11. xdep0
12. xdep
13. cdep
14. coxe
15. coxp
16. coxeff
17. lt0
18. lt
19. ltw
20. phi
21. phis
22. VFB
23. vgse
24. vgsteff
25. vbseff
26. vdseff
27. vth0
28. bulk effect k1 = term[0]
29. bulk effect k2 = term[1]
30. pocket implant = term[2]
31. narrow channel effect = term[3]
32. short channel effect = term[4]
33. small channel effect = term[5]
34. high vds effect = term[6]
35. vth

36. f_doping
37. abulk
38. litl
39. ueff
40. esat
41. rds
42. rd
43. rs
44. vdsat
45. ids0 (without resistance)
46. idsr (with resistance)
47. vasat
48. vaclm
49. va
50. cclm
51. vadits
52. vadibl
53. inv_vascbe
54. ids (with output resistance)
55. vth_dits
56. n
57. vfbsd
58. actual version

Example call in PEL:

```
erg = BSIM4_DC_calculate(par, point_vd, point_vg, 0,
   point_vb, MAIN.L, MAIN.W, MAIN.NF, 0, 0, TEMP, TYPE, 0)
```

BSIM430_DC_calculate Calculates the drain current of the BSIM4.3.0 model and different internal states of the model for the given terminal voltages vd, vg, vs and vb. The type of internal state, for example, the drain source resistance rds can be selected by the select output flag. In some cases, it is necessary to use a measured value for the threshold voltage instead of the calculated. Use the select input flag to select measured or calculated. If this is not equal to zero, then the value in value input is used for vth instead of the calculated one.

Input arguments:

Input:	Parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	vd Drain voltage vg Gate voltage vs Source voltage vb Bulk voltage Length (L) Gate length Width (W) Gate width SA Distance between OD edge to poly from one side SB Distance between OD edge to poly from other side SD Distance between neighboring fingers Number fingers (NF) Number of gate fingers select input (if 1 use value input for Vth) value input (value input for Vth if select input = 1)
Parameters:	-

Output:

Vector with BSIM4 internal states for the given DC bias point.
By setting debug = 1, this vector is printed with explanations:

0. leff
1. weff
2. weffs
3. weffcj
4. dl
5. dws
6. vtm0
7. eg0
8. ni
9. vbi
10. vbc
11. xdep0
12. xdep
13. cdep
14. coxe
15. coxp
16. coxeff
17. lt0
18. lt
19. ltw
20. phi
21. phis
22. VFB
23. vgse
24. vgsteff
25. vbseff
26. vdseff
27. vth0
28. bulk effect k1 = term[0]
29. bulk effect k2 = term[1]
30. pocket implant = term[2]
31. narrow channel effect = term[3]
32. short channel effect = term[4]
33. small channel effect = term[5]
34. high vds effect = term[6]
35. vth
36. f_doping

37. abulk
38. litl
39. ueff
40. esat
41. rds
42. rd
43. rs
44. vdsat
45. ids0 (without resistance)
46. idsr (with resistance)
47. vasat
48. vaclm
49. va
50. cclm
51. vadits
52. vadibl
53. inv_vascbe
54. ids (with output resistance)
55 vth_dits
56. n
57. vfbsd
58. actual version

Example call in PEL:

```
erg = BSIM430_DC_calculate(par, point_vd, point_vg, 0,
point_vb, MAIN.L, MAIN.W, MAIN.NF, MAIN.SA, MAIN.SB,
MAIN.SD, 0, 0, TEMP, TYPE, 0)
```

BSIM450_DC_calculate Calculates the drain current of the BSIM4.3.0 model and different internal states of the model for the given terminal voltages vd, vg, vs and vb. The type of internal state, e.g. the drain source resistance rds can be selected by the select output flag. In some cases, it is necessary to use a measured value for the threshold voltage instead of the calculated. Use the select input flag to select measured or calculated. If this is not equal to zero, then the value in value input is used for *vth* instead of the calculated one.

Input Arguments:

Input:	Parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	vd Drain voltage vg Gate voltage vs Source voltage vb Bulk voltage Length (L) Gate length Width (W) Gate width SA Distance between OD edge to poly from one side SB Distance between OD edge to poly from other side SD Distance between neighboring fingers SCA Integral of the first distribution function for scattered well dopant SCB Integral of the second distribution function for scattered well dopant SCC Integral of the third distribution function for scattered well dopant SC Distance to a single well edge Number fingers (NF) Number of gate fingers select input (if 1 use value input for Vth) value input (value input for Vth if select input = 1)

Parameters: -

Output: Vector with BSIM4 internal states for the given DC bias point.
By setting debug = 1, this vector is printed with explanations:

0. leff
1. weff
2. weffs
3. weffcj
4. dl
5. dws
6. vtm0
7. eg0
8. ni
9. vbi
10. vbc
11. xdep0
12. xdep
13. cdep
14. coxe
15. coxp
16. coxeff
17. lt0
18. lt
19. ltw
20. phi
21. phis
22. VFB
23. vgse
24. vgsteff
25. vbseff
26. vdseff
27. vth0
28. bulk effect k1 = term[0]
29. bulk effect k2 = term[1]
30. pocket implant = term[2]
31. narrow channel effect = term[3]
32. short channel effect = term[4]
33. small channel effect = term[5]
34. high vds effect = term[6]

35. vth
36. f_doping
37. abulk
38. litl
39. ueff
40. esat
41. rds
42. rd
43. rs
44. vdsat
45. ids0 (without resistance)
46. idsr (with resistance)
47. vasat
48. vaclm
49. va
50. cclm
51. vadits
52. vadibl
53. inv_vascbe
54. ids (with output resistance)
55 vth_dits
56. n
57. vfbsd
58. actual version

Example call in PEL:

```
erg = BSIM450_DC_calculate(par, point_vd, point_vg, 0,
point_vb, MAIN.L, MAIN.W, MAIN.NF, MAIN.SA, MAIN.SB,
MAIN.SD, MAIN.SCA, MAIN.SCB, MAIN.SCC, MAIN.SC, 0, 0,
TEMP, TYPE, 0)
```

BSIM4_DC_extr_A0_AGS_KETA Extract model parameters A0, AGS, KETA from the measurement:

id = f(Vgs) @ diff. Vbs @ high Vds

from a transistor with large and wide gate length.

Input Arguments:

Input:	parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	Length (L) Width (W) Number fingers (NF) Temperature (Degree C) Type (1=NMOS, -1=PMOS) Debug (1: show internal states of the function 0:)
Parameters:	path to setup vd vg vb id type id
Output:	Value of: output[0] = a0 output[1] = ags output[2] = keta In the case of an error, all 3 outputs are set to 1e99
Extracts:	A0, AGS, KETA

Example call in PEL:

```
erg = BSIM4_DC_extr_A0_AGS_KETA(par, MAIN.L, MAIN.W,
       MAIN.NF, TEMP, TYPE, 0,".","vd","vg","vb","id")
```

BSIM4_DC_get_parameter This function loads all BSIM4 model parameters from the actual model parameter set and checks them for consistency. Without finding errors, the function gives back an array with model parameters in a given order.

Output: Array of BSIM4 model parameters in the following order:

```
error = outputs[0]; ! in case of an
  ! error during the parameter
check
  ! error would be set to 1e-99
LEVEL = outputs[1];
VERSION = outputs[2];
MOBMOD = outputs[3];
RDSMOD = outputs[4];
IGCMOD = outputs[5];
IGBMOD = outputs[6];
GEOMOD = outputs[7];
EPSROX = outputs[8];
TOXE = outputs[9];
TOXP = outputs[10];
TOXM = outputs[11];
DTOX = outputs[12];
XJ = outputs[13];
NDEP = outputs[14];
NGATE = outputs[15];
NSD = outputs[16];
XT = outputs[17];
RSH = outputs[18];
RSHG = outputs[19];
VTH0 = outputs[20];
PHIN = outputs[21];
K1 = outputs[22];
K2 = outputs[23];
K3 = outputs[24];
K3B = outputs[25];
W0 = outputs[26];
LPE0 = outputs[27];
LPEB = outputs[28];
VBM = outputs[29];
DVT0 = outputs[30];
DVT1 = outputs[31];
DVT2 = outputs[32];
DVTP0 = outputs[33];
DVTP1 = outputs[34];
```

```
DVT0W = outputs[35];
DVT1W = outputs[36];
DVT2W = outputs[37];
U0 = outputs[38];
UA = outputs[39];
UB = outputs[40];
UC = outputs[41];
EU = outputs[42];
VSAT = outputs[43];
A0 = outputs[44];
AGS = outputs[45];
B0 = outputs[46];
B1 = outputs[47];
KETA = outputs[48];
A1 = outputs[49];
A2 = outputs[50];
WINT = outputs[51];
LINT = outputs[52];
DWG = outputs[53];
DWB = outputs[54];
VOFF = outputs[55];
VOFFL = outputs[56];
MINV = outputs[57];
NFACTOR = outputs[58];
ETA0 = outputs[59];
ETAB = outputs[60];
DSUB = outputs[61];
CIT = outputs[62];
CDSC = outputs[63];
CDSCB = outputs[64];
CDSCD = outputs[65];
PCLM = outputs[66];
PDIBLC1 = outputs[67];
PDIBLC2 = outputs[68];
PDIBLCB = outputs[69];
DROUT = outputs[70];
PSCBE1 = outputs[71];
PSCBE2 = outputs[72];
PVAG = outputs[73];
DELTA = outputs[74];
FPROUT = outputs[75];
```

```
PDITS = outputs[76];
PDITSL = outputs[77];
PDITSD = outputs[78];
RDSW = outputs[79];
RDSWMIN = outputs[80];
RDW = outputs[81];
RDWMIN = outputs[82];
RSW = outputs[83];
RSWMIN = outputs[84];
PRWG = outputs[85];
PRWB = outputs[86];
WR = outputs[87];
ALPHA0 = outputs[88];
ALPHA1 = outputs[89];
BETA0 = outputs[90];
AGIDL = outputs[91];
BGIDL = outputs[92];
CGIDL = outputs[93];
EGIDL = outputs[94];
AIGBACC = outputs[95];
BIGBACC = outputs[96];
CIGBACC = outputs[97];
NIGBACC = outputs[98];
AIGBINV = outputs[99];
BIGBINV = outputs[100];
CIGBINV = outputs[101];
EIGBINV = outputs[102];
NIGBINV = outputs[103];
AIGC = outputs[104];
BIGC = outputs[105];
CIGC = outputs[106];
AIGSD = outputs[107];
BIGSD = outputs[108];
CIGSD = outputs[109];
DLCIG = outputs[110];
NIGC = outputs[111];
POXEDGE = outputs[112];
PIGCD = outputs[113];
NTOX = outputs[114];
TOXREF = outputs[115];
DWJ = outputs[116];
```

```
TNOM = outputs[117];
UTE = outputs[118];
KT1 = outputs[119];
KT1L = outputs[120];
KT2 = outputs[121];
UA1 = outputs[122];
UB1 = outputs[123];
UC1 = outputs[124];
AT = outputs[125];
PRT = outputs[126];
WL = outputs[127];
WLN = outputs[128];
WW = outputs[129];
WWN = outputs[130];
WWL = outputs[131];
LL = outputs[132];
LLN = outputs[133];
LW = outputs[134];
LWN = outputs[135];
LWL = outputs[136];
WLC = outputs[137];
WWC = outputs[138];
WWLC = outputs[139];
XL = outputs[140];
XW = outputs[141];
BINUNIT = outputs[142];
LAMBDA = outputs[143];
VTL = outputs[144];
XN = outputs[145];
LC = outputs[146];
SAREF = outputs[147];
SBREF = outputs[148];
WLOD = outputs[149];
KU0 = outputs[150];
KVSAT = outputs[151];
TKU0 = outputs[152];
LKU0 = outputs[153];
WKU0 = outputs[154];
PKU0 = outputs[155];
```

```
LLODKU0 = outputs[156];
WLODKU0 = outputs[157];
KVTH0 = outputs[158];
LKVTH0 = outputs[159];
WKVTH0 = outputs[160];
PKVTH0 = outputs[161];
LLODVTH = outputs[162];
WLODVTH = outputs[163];
STK2 = outputs[164];
LODK2 = outputs[165];
STETA0 = outputs[166];
LODETA0 = outputs[167];
TEMPMOD = outputs[168];
UD = outputs[169];
UP = outputs[170];
LP = outputs[171];
UD1 = outputs[172];
TVFBSDOFF = outputs[173];
TVOFF = outputs[174];
WEB = outputs[175];
WEC = outputs[176];
KVTH0WE = outputs[177];
K2WE = outputs[178];
KU0WE = outputs[179];
SCREF = outputs[180];
WPEMOD = outputs[181];
```

Example call in PEL:

```
par = BSIM4_DC_get_parameter()
```

BSIM4_DC_vth Picks up 1 single sweep curve of id=f(vg) of a specified setup and extracts the threshold voltage vth. The setup is specified by the parameters path to vd, ... etc. This makes it easier to call the function with variable inputs inside the PEL programs.

The 'Flag' variable is used to define certain conditions, for example, the extraction of vth for the large device that does not need to calculate all the early voltage values.

Input Arguments:

Input:	parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	Length (L) Width (W) Flag for extraction options flag: 0 Large device @ low vds 1 Short and small device @ low vds 2 Short and small device @ high vds 3 A constant reference current Idref = ID_REF_VTH*W/L is used where ID_REF_VTH is a model variable. # of curve Number fingers (NF) Temperature (Degree C) Type (1=NMOS, -1=PMOS) Debug (1: show internal states of the function 0: nothing)
Parameters:	path to setup vd vg vb id type id
Output:	Value vth or failure indicator
Extracts:	Vth (1e99 indicates error)

Example call in PEL:

```
erg = BSIM4_DC_vth(par, MAIN.L, MAIN.W, flag, i, MAIN.NF,
       TEMP, TYPE, 0, ".", "vd","vg","vb","id","M")
```

BSIM430_DC_vth "Picks up one single sweep curve of id=f(vg) of a specified setup and extracts the threshold voltage Vth. The setup is specified by the parameters path to *vd*, ... etc. This function should only be used with model versions BSIM4.3 and higher.

Input Arguments:

Input:	Parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	Length(L) Width (W) Number fingers (NF) SA SB SD Flag for extraction options flag: 0 Large device @ low vds 1 Short and small device @ low vds 2 Short and small device @ high vds 3 A constant reference current Idref = ID_REF_VTH*W/L is used Reference current ID_REF_VTH for extraction options 3 # of curve Temperature (Degree C) Type (1=NMOS, -1=PMOS) Debug (1: show internal states of the function 0: nothing)
Parameters:	path to setup vd vg vb id type id
Output:	Value vth or failure indicator
Extracts:	Vth (1e99 indicates error)

Example call in PEL:

```
erg = BSIM430_DC_vth(par, MAIN.L, MAIN.W, MAIN.NF,
MAIN.SA, MAIN.SB, MAIN.SD, flag, ID_REF_VHT, i,  TEMP,
TYPE, 0, ".", "vd","vg","vb","id","M")
```

BSIM450_DC_vth Picks up one single sweep curve of *id=f(vg)* of a specified setup and extracts the threshold voltage *Vth*. The setup is specified by the parameters path to *vd*, ... etc. This function should only be used with model versions BSIM4.5 and higher.

Input Arguments:

Input:	Parameter set (get with 'BSIM4_DC_get_parameter()')
Variables:	Length(L) Width (W) Number fingers (NF) SA SB SD SCA SCB SCC SC Flag for extraction options flag: 0 Large device @ low vds 1 Short and small device @ low vds 2 Short and small device @ high vds 3 A constant reference current Idref = ID_REF_VTH*W/L is used 4 A constant reference current Idref = ID_REF_VTH*(W-2*Delta W)/(L-2*Delta L)

Reference current ID_REF_VTH for extraction options 3,4
Delta L (one side) for extraction options 4
Delta W (one side) for extraction options 4
# of curve
Temperature (Degree C)
Type (1=NMOS, -1=PMOS)
Debug (1: show internal states of the function 0: nothing)

Parameters: path to setup
vd
vg
vb
id
type id

Output: Value vth or failure indicator

Extracts: Vth (1e99 indicates error)

Example call in PEL:

```
erg = BSIM450_DC_vth(par, MAIN.L, MAIN.W, MAIN.NF,
MAIN.SA, MAIN.SB, MAIN.SD, MAIN.SC, MAIN.SCA, MAIN.SCB,
MAIN.SCC, flag, i,  TEMP, TYPE, 0, ".",
"vd","vg","vb","id","M")
```

BSIM4_error This function takes a set of measured and simulated data and calculates the error between simulation and measurement in the specified range (xmin, xmax, ymin, ymax). The error is given back as output. In addition, the maximum error and the root mean square (RMS) error are given back through an IC-CAP system variable.

Input Arguments:

Inputs: x-coordinate values
measured y-coordinate values
simulated y-coordinate values

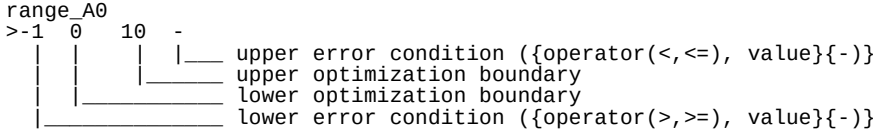
Variables:	x_min x_max y_min y_max
Parameters:	IC-CAP Variable to write MAX_ERROR IC-CAP Variable to write RMS_ERROR
Output:	error in the specified range, all other points of the output = 0

Example call in PEL:
error = BSIM4_error(vg,id.m,id.s,0,3,0,1e-6,"MAX_ERROR", "RMS_ERROR")

BSIM4_set_opt The function accepts a list of model parameters, separated by blanks (e.g., “A0 AGS KETA”) and searches the range information for these parameters in the *range_<PARAMETER>* variables in the referenced path.

After analyzing the range information for each parameter, the variables *min_<PARAMETER>* and *max_<PARAMETER>* in the local setup/DUT are set. These variables can be used as upper/lower limit in an optimizer call.

The range information is stored in a string in the following format:



Input Arguments:

Parameters:	Parameter names, separated by blanks Path to parameter range definition

Output:	Flag for correct operation: 0: everything is ok -1: error during function execution (e.g., variable 'range_xx' not found)

Example call in PEL:

```
erg = BSIM4_set_opt("RDSW PRWG
       PRWB","Extraction_configuration/Boundaries")
```

BSIMCV_total_cap This function is obsolete.

Extracts the total PN junction capacitance parameters from the bottom and sidewall for the BSIM1 and BSIM2 models. Requires C-V measurement on 2 different geometries. The first measurement should be on a device in which the bottom capacitance dominates. The second measurement should be on a device in which the sidewall capacitance dominates.

Input Arguments:	
Data Sets:	Cap 1, Cap 2, Junction V
Reals or Integers:	Cap 1 Area, Cap 1 Perim, Cap 2 Area, Cap 2 Perim
Output:	None
Extracts:	CJ, MJ, CJSW, MJSW, PB
Automatic Invocation:	By Extract menu function

ceil Returns the smallest integer not less than the given value.

Input Arguments:	
Reals:	Number
Output:	Single real
Automatic Invocation:	On Input Change

check_error_log Checks the *.icerrlog* file to see if any error messages were logged during the execution of the previous function. The log file can be viewed using any text editor (or in a terminal window using *more .icerrlog*). Note: the *.icerrlog* file is cleared each time you start IC-CAP.

Input Arguments:

Strings/Pars/Vars:	mpme
Output:	Returns 0 if no errors; non-zero if errors are logged.
Automatic Invocation:	MANUAL

PEL Example

```
x = check_error_log()
```

circlefit Performs a circlefit on a set of complex data centered on the REAL axis. Returns a 2 point data set containing the center and radius. If the OVERRIDE_LIMITS variable is TRUE, the limits can be specified manually with the X_LOW and X_HIGH variables. These limits will always apply to the first Sweep in the Setup.

Input Arguments:

Data Sets:	Input
Reals or Integers:	Step Number (0 is first)
Output:	Array of 2 points: center then radius
Automatic Invocation:	None

conjg Complex conjugate function.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)

Automatic Invocation: On Data Set Input Change

Connect Switching matrix function. Used to connect or disconnect the specified port and pin. Initialize the switching matrix with *SWM_init* before this function. For more information regarding this function, refer to "External Matrix Driver User Functions" on page 166.

Input Arguments:
- Reals or Integers: Port Addr, Pin Number

Output: Single number with exit status.

Automatic Invocation: None

copy2output Copies the input data set to a measured or simulated output data set.

correlation Calculates the correlation coefficient for 1 data set versus another, at a particular curve (step number). Indicates the degree to which the 2 data sets share a linear dependence.

Input Arguments:
- Data Sets: Input 1, Input 2
- Reals or Integers: Step Number (0 is first)

Output: single value in the interval [-1,1]

Automatic Invocation: On Data Set Input Change

cos Cosine of an angle in radians.

Input Arguments:
- Data Sets: Input 1

Output: Complex number, matrix, complex array, or matrix array (depends on input argument)

Automatic Invocation: On Data Set Input Change

cosh Hyperbolic cosine.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

dataset Enables you to access the dataset referred to by a string. A second argument may be specified that is a variable to receive any error string normally going to a red error box.

Example:

```
x=dataset("/npn/dc/fgummel/vb")
print x[4]
x=dataset("/npn/dc/fgummel/badname",errstr)
if errstr<>"" then print errstr
```

If you try to run a transform that uses the dataset() function, a warning message appears in the Status window. The message appears since you are creating a transform that depends on data in another output or transform. However, each time you run the transform, you could depend on a *different* set of data because the argument to dataset() is only known at run-time and could change each time you run the transform.

IC-CAP can't track this dependency as it does all other dependencies. Since it can't track the dependency, it cannot automatically execute the transform, and it sends the warning message to the Status window.

To prevent the error message from appearing, you can set up a transform that does not require automatic updating when the argument in dataset() is updated. If automatic updating is not needed, you can suppress the warning by prepending the word *quiet* to the dataset() argument as shown in this example:

```
x=dataset("quiet "&mydata)
```

where *mydata* is the string containing the name of the data you want to access.

derivative This function has been deprecated. Use the derivative2 function instead for calculating derivatives.

Calculates the derivative of data set Y relative to data set X. The order can be specified. A 3-point numerical derivative formula is used, except for the endpoints, where a 2-point formula is used.

Input Arguments:

Data Sets:	X Data, Y Data
Reals or Integers:	Order
Output:	Array of real numbers; size determined by number of points in setup
Automatic Invocation:	On Data Set Input Change

derivative2 Calculates the derivative of data set Y relative to data set X. The order can be specified. The number of points per sweep can be specified. If number of points per sweep is set to 0, then the data is assumed to be a single curve. If number of points per sweep is set to -1, then the function will act as the same derivative function, requiring the local setup to determine the number of points per curve. If number of points is >=0 then the function may be called on any arbitrary sets of data of the same size, even from a macro.

A 3-point numerical derivative formula is used, except for the endpoints, where a 2-point formula is used.

Input Arguments:

Data Sets:	X Data, Y Data
Reals or Integers:	Order, Points per sweep

Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

DIODEDCmod_ia Given the forward diode voltage, the anode current is calculated according to the UCB diode model.

Input Arguments:

Data Sets:	Diode V
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

EEbjt2_ce_dc_iv Solves for the dependent terminal characteristic (current or voltage) at the input or output port given any combination of independent variables.

Usage:	EEbjt2_ce_dc_iv(<Port 1 Input>, <Port 2 Input>, <Port 1 Mode>, <Port 2 Mode>, <Output Port>)

Input Arguments:

<Port 1 Input>	Current or voltage dataset for port 1
<Port 2 Input>	Current or voltage dataset for port 2
<Port 1 Mode>	Port 1 mode, “V” for voltage or “I” for current
<Port 2 Mode>	Port 2 mode, “V” for voltage or “I” for current
<Output Port>	Port number for output dataset (“1” or “2”)

Example PEL statement:

```
icf_gummel = EEbjt2_ce_dc_iv(vb, vc, "V", "V", "2")
```

EEbjt2_ce_ss_elements Computes the intrinsic conductance, transconductance, capacitance or transcapacitance at the input or output port of the bjt2 model.

Usage: EEbjt2_ce_ss_elements(<Port 1 Input>, <Port 2 Input>, <Port 1 Mode>, <Port 2 Mode>, <Element Name>)

Input Arguments:

<Port 1 Input>	Current or voltage dataset for port 1
<Port 2 Input>	Current or voltage dataset for port 2
<Port 1 Mode>	Port 1 mode, “V” for voltage or “I” for current
<Port 2 Mode>	Port 2 mode, “V” for voltage or “I” for current
<Element Name>	Desired linear conductance (“G11”, “G12”, “G21”, “G22”) or capacitance (“C11”, “C12”, “C21”, “C22”)

Example PEL statement:

```
g11 = EEbjt2_ce_ss_elements(ibase, vce, "I", "V", "G11")
```

EEbjt2_extrinsic_ckt Embeds the effect of the extrinsic elements onto s-parameter data, or de-embeds the effect of the extrinsic elements from s-parameter data. Resistances and inductances are series elements separated by the shunt capacitances Cxbc, Cxbe and Cxce. If the input s-parameter dataset is of the same size as the frequency dataset in the referenced setup, then it is assumed that the s-parameters vary over the frequencies specified and these frequencies will be used in the embedding or de-embedding operation. In this case, the <Frequency> parameter is not used. If however, the input s-parameter dataset has a size which differs from that of the frequency dataset in the referenced

setup, the data points is assumed to be at a single frequency. This frequency value is specified by the <Frequency> parameter.

Usage:	EEbjt2_extrinsic_ckt(<S-pars>, <de-embed ?>, <Frequency>, <Setup path>, <Lb>, <Lc>, <Le>, <Cxbc>, <Cxbe>, <Cxce>, <Rb>, <Rc>, <Re>)

Input Arguments:

<S-pars>	S-parameter dataset name to be embedded or de-embedded
<de_embed ?>	Controls whether the function embeds (“no”) or de-embeds (“yes”)
<Frequency>	Variable containing the frequency value of the s-parameter data
<Setup path>	Variable containing the setup path of the frequency dataset
<Lb>	Parameter for base inductance
<Lc>	Parameter for collector inductance
<Le>	Parameter for emitter inductance
<Cxbc>	Parameter for base-collector capacitance
<Cxbe>	Parameter for base-emitter capacitance
<Cxce>	Parameter for collector-emitter capacitance
<Rb>	Parameter for base resistance
<Rc>	Parameter for collector resistance
<Re>	Parameter for emitter resistance

Example PEL statement:

```
s_mod = EEbjt2_extrinsic_ckt(s_mod_int, "no", FREQ_CAP,
         PATH, Lb, Lc, Le, C1, C2, C3, Rb, Rc, Re)
```

EEbjt2_Is_N Extracts saturation current and ideality factor for diodes or Gummel-Poon type BJTs. For extraction of Gummel-Poon collector currents, the value of the early voltage can be input. For standard diodes or Gummel-Poon base currents, a large value for <Fwd/Rev Va> should be used so as to remove this effect from the extraction.

Usage:	EEbjt2_Is_N(<Vj>, <Ij>, <Fwd/Rev Is>, <Fwd/Rev N>, <Fwd/Rev Va>, <Vmin>, <Vmax>)
Input Arguments:	
<Vj>	Input dataset containing voltage data
<Ij>	Input dataset containing current data
<Fwd/Rev Is>	Model parameter to be assigned the extracted Is value
<Fwd/Rev N>	Model parameter to be assigned the extracted N value
<Fwd/Rev Va>	Parameter or variable that contains the early voltage value
<Vmin>	Variable that contains the minimum voltage value of data to be used in the extraction
<Vmax>	Variable that contains the maximum voltage value of data to be used in the extraction

EEbjt2_mdl Saves model parameters to a Series IV formatted file.

Usage:	EEbjt2_mdl(<Mdl File Name>)
Input Arguments:	
<Mdl File Name>	The file name that will contain the “MDIF” formatted data

Example PEL statement:

```
dummy_result = EEbjt2_mdl("generic_bjt.txt")
```

EEfet3_ckt Returns the value of the selected linear equivalent circuit element.

Usage: EEfet3_ckt(Vg, Vd, <ckt_par_name>)

Vg and Vd are data sets that contain the bias conditions where the linear equivalent circuit is computed. The desired equivalent circuit element name is supplied in the third parameter as a text string. Equivalent circuit element names are: cgs, cgd, cds, ris, rid, gm and gds. The conductances gma and gds are AC values and should be compared with those extracted from S-parameter data.

PEL example that returns the computed requested element value.

```
Cgs_data = EEfet3_ckt(Vg, Vd, “cgs”)
Cgd_data = EEfet3_ckt(Vg, Vd, “cgd”)
Cds_data = EEfet3_ckt(Vg, Vd, “cds”)
Ris_data = EEfet3_ckt(Vg, Vd, “ris”)
Rid_data = EEfet3_ckt(Vg, Vd, “rid”)
Gm_data = EEfet3_ckt(Vg, Vd, “gm”)
Tau_data = EEfet3_ckt(Vg, Vd, “tau”)
Gds_data = EEfet3_ckt(Vg, Vd, “gds”)
```

EEfet3_cs_dc_iv Computes the model’s common source bias response.

Usage: EEfet3_cs_dc_iv (Data_port_1, Data_port_2, Mode_port_1, Mode_port_2, response_port)

This function returns a data set containing the bias response at the port specified by the fifth parameter (response_port). The first 2 parameters are data sets that contain the bias conditions forced at the respective ports. The next 2 parameters are strings that indicate whether current “I” or voltage “V” is being forced. The fifth parameter is an index that specifies which port’s (1 or 2) bias response will be contained in the data set returned.

PEL Example:

```
Ids = EEfet3_cs_dc_iv(Vg, Vd, “V”, “V”, 2)
Igs = EEfet3_cs_dc_iv(Vg, Vd, “V”, “V”, 1)
Vds = EEfet3_cs_dc_iv(Vg, Id, “V”, “I”, 2)
Vgs = EEfet3_cs_dc_iv(Ig, Vd, “I”, “V”, 1)
```

EEfet3_lecp Returns the requested linear equivalent circuit parameter value extracted from measured S-parameter data.

Usage: EEfet3_lecp (Vg, Vd, <ckt_par_name>)

This function is used in conjunction with EEfet3_s2ckt() to extract and display linear equivalent circuit parameters from measured S-parameter data. EEfet3_s2ckt does the extraction of linear equivalent circuit parameters from measured S-parameters and stores them internally to ICCAP. EEfet3_lecp retrieves the linear equivalent circuit parameter values. The specific element returned is requested by the string in the third field of the function call. Valid equivalent circuit element names are cgs, cdg, cds, ris, rid, gm, and gds. An error condition will be flagged if a bias condition is specified in EEfet3_lecp that was not in the data stored by a previous call to EEfet3_s2ckt.

PEL example that returns the computed requested element value.

```
Cgs_data = EEfet3_lecp(Vg, Vd, “cgs”)
Cgd_data = EEfet3_lecp(Vg, Vd, “cgd”)
Cds_data = EEfet3_lecp(Vg, Vd, “cds”)
Ris_data = EEfet3_lecp(Vg, Vd, “ris”)
Rid_data = EEfet3_lecp(Vg, Vd, “rid”)
Gm_data = EEfet3_lecp(Vg, Vd, “gm”)
Tau_data = EEfet3_lecp(Vg, Vd, “tau”)
Gds_data = EEfet3_lecp(Vg, Vd, “gds”)
```

EEfet3_mdl Saves model parameters to a Series IV formatted file.

Usage: EEfet3_mdl(“file_name.txt”)

This function returns no data or result code. Upon execution, an “MDIF” formatted data file containing the existing set of model parameters is written to the current working directory.

PEL example that saves a data file that can be read by Series IV simulators.

```
dummy_result = EEfet3_mdl(“MRF_901.par”)
```

EEfet3_model_name A utility function that copies the model name into the variable passed in as the argument.

Usage: EEfet3_model_name(variable):

Since PEL only has direct access to the relative path name of local transforms and variables, this function parses out the model's "root" name and copies it as a string to the variable specified as the argument. After execution, the argument variable will contain a string containing the model name.

Note: This function can be used with any model file; it is not restricted to EEfet3.

PEL example that copies the model name into the variable "MyName."

```
dummy_result = EEfet3_modle_name(MyName)
```

EEfet3_package A utility function that can either "embed or de-embed" the effects of a package from S-parameter data provided as input. The resultant set of S-parameters is returned as a data set with the same frequency and bias conditions as the input S-parameter data set.

Usage: Efet3_package(S_parameter_data_set, embed/deembed_flag, Rg, Rd, Rs, Lg, Ld, Ls, Cxgs, Cxds, Cxgd, Z0_gate, length, effective_velocity, Z0_drain, length, effective_velocity, Z0_source, length, effective_velocity)

This function either embeds or de-embeds the S-parameters provided as input. The package topology used here is a very simple series shunt representation of a component's package. The elements represented in the argument list work from the intrinsic device to the outside wall of the package. The bond wire and contact resistances are represented by the arguments: Rg, Rd, Rs, Lg, Ld, Ls. The arguments Rg and Lg are the input port's (gate) series inductance and resistance.

Rs and Ls are the common lead's inductance and resistance. Rd and Ld are the output lead's contact resistance and bond inductance.

Three shunt capacitances are next and represent stray capacitance of the package. Cxgs is connected from the outside of the series impedances from gate-to-source nodes just described. Cxgd is connected from the outside of the series impedance from the gate to drain nodes just described. Cxds is connected from the outside of the series impedance from drain to source as just described.

The final series elements of the package model are transmission lines. Z0_gate, length and effective velocity describe the input transmission line connected at the gate terminal of the package to the modified gate node just outlined above. Z0_drain, length and effective velocity describe the output transmission line connected at the drain terminal of the package to the modified drain node just outlined above. There is no common lead transmission line in this package model.

Because you must use the same values for each of these arguments in many places in the IC-CAP model file, this function is constructed to use model variables as arguments. First: create 1 variable, in the model variable table, for each of the function arguments (thus making it global to the entire model in use). Then use the variables each time the function is used. In this manner you can ensure that the same values are being used to embed the model as were extracted from measurements.

The first argument is the data set upon which the function will operate. The second argument is a text string or variable containing a text string "embed" or "deembed." The function will operate on the input data set as indicated by the second argument.

PEL example that de-embeds a package from a measurement:

```
s_intrinsic = EEfet3_package(measured_s, "deembed", Rin,
Rout, Rcommon, Lin, Lout, Lcommon, Cx_InToCommon, CxInToOut,
CxOutToCommon, Z0_in, L_in, Evel, Z0_out, L_out, Evel)
```

EEfet3_ResCheck Verifies and adjusts variables that are used to control swept measurements.

Usage: EEfet3_ResCheck(Start, Stop, Number_of_Points, resolution)

Each argument of EEfet3_ResCheck is a model variable. These variables are used in DUT/Setups to control measurements. Each type of measurement equipment has resolution limitations. Start, stop, and step size must be within the equipment's resolution before a measurement can be successful. For example, the HP/Agilent 4142 cannot resolve voltages with greater accuracy than 1 millivolt. There are several conditions that must be accounted for to guarantee proper control of the measurement equipment in use.

The following sequence of steps should be followed to ensure that equipment limitations are not violated. First, the start value is rounded to a "resolvable" measurement value as specified by the argument "resolution." The end point is then rounded. The step size is then calculated [step = (stop-start) / points] and rounded to the proper resolution. The end point is then re-computed and adjusted to exactly fit the number of steps requested [stop = start + step * points]. Because of this adjustment, you may see the "stop" point change after this function is called. The last case is where the step size is below the minimum resolution. In this case, the step size is set to the minimum resolution and the starting point is placed that number of points away and the number of points is adjusted. The "resolution" argument is the only value that will not change upon execution of this function.

PEL Example:

```
dummy_result = EEfet3ResCheck(Vstart, Vstop, NumPoints,
                                    v_res)
```

EEfet3_Rs_delta_m Returns a data set that contains the change in measured Vgs when very specific bias currents are forced at the gate and drain terminals.*

Usage: EEfet3_Rs_delta_m (Ig, Id, Vg, Vd)

Vgs is measured at 2 values of Ids while Igs is swept. Ids is chosen such that Vds is on the order of 2 tenths of a volt (the FET must be in the region of linear operation). Igs is fifty to one hundred times smaller than Ids. The change in Vgs is then proportional to Rs.

The expressions for the change in Vgs are a complicated function of Rs. Since these expressions cannot be solved for Rs directly, optimization is used to find a value of Rs that makes measured and simulated values of delta Vgs match.

PEL Example:

```
Delta_Vgs = EEfet3_Rs_delta_m(Ig,Id,Vg,Vd)
```

*This method of extracting Rs is based on: “New Method to Measure the Source and Drain Resistance of the GaAs MESFET” Long Yang and Steven Long, IEEE Electron Device Letters Vol EDL-7 No. 2, February 1986.

EEfet3_Rs_delta_s Returns a data set that contains the change in simulated Vgs given the same bias conditions specified when EEfet3_Rs_delta_m was extracted.*

Usage: EEfet3_Rs_delta_s (Ig, Id, Vg, Vd)

This simulation function for delta Vgs uses EEfet3 model parameters Rs and N, the gate diode's emission coefficient. Since these expressions cannot be solved for Rs directly, optimization is used to find a value of Rs that makes measured and simulated values of delta Vgs match. Note that N must be accurately determined before this method of extracting Rs can be successful.

PEL Example:

```
Delta_Vgs_Simulated = EEfet3_Rs_delta_s(Ig,Id,Vg,Vd)
```

*This method of extracting Rs is based on: “New Method to Measure the Source and Drain Resistance of the GaAs MESFET” Long Yang and Steven Long, IEEE Electron Device Letters Vol EDL-7 No. 2, February 1986.

EEfet3_s2ckt Converts S-parameters to a table of linear equivalent circuit element values.

Usage: EEfet3_ s2ckt (S_parameter, Frequency, Vg, Vd, Conductance_Frequency, Capacitance_Frequency, Delay_Frequency)

This function returns a data set containing S-parameters computed from a linear equivalent circuit model. Element values for the linear equivalent circuit model are extracted from the input S-parameter data set. The table of element values for the linear equivalent circuit model are stored internally to IC-CAP and can be accessed using EEfet3_lecp(). In this manner, you can both examine how well the linear equivalent circuit model fits measured S-parameter data over frequency and see how the element values behave over bias.

The reason for this 2-step process is that each IC-CAP function can only return a data set of the same type and dimension as the input data set. In the first step (EEfet3_s2ckt) S-parameters are input (over frequency and bias) and a computed set of S-parameters is returned (over frequency and bias). The values of the linear equivalent circuit model extracted are saved in a special internal structure. The second step is to create a DUT/Setup that only sweeps bias, not frequency. The function EEfet3_lecp is then used to access the internal data structure and return the linear equivalent circuit element value requested. The output is then of the same type and array size as the bias range. Element values can then be plotted against bias.

PEL Example:

```
computed_s_parameters = EEfet3_s2ckt(s_data, freq, Vg, Vd,
                                     FG, FC, Ftau)
```

and in another DUT/Setup the next function recalls Cgs saved

```
Cgs_data = EEfet3_lecp(Vg, Vd, “cgs”)
```

EEfet3_spars Computes modeled S-parameters based on the current set of model parameters.

Usage: EEfet3_ spars (measured_S_parameter_data_set, Frequency, Vg, Vd)

Computes the bias-dependent model's intrinsic S-parameters at each bias and frequency specified. The S-parameter data set used as an input is only for the purpose of defining the type and quantity of data this function will supply as an output. Typical use would be comparing the computed set of S-parameters to a set of measured data and using that measured data as the S-parameter data set supplied as input to this function

PEL Example:

```
computed_s_parameters = EEfet3_spars(s_data, freq, Vg, Vd)
```

EEmos1_ckt This function is obsolete.

Returns the value of the selected linear equivalent circuit element

Usage: EEmos1_ckt(Vg, Vd, <ckt_par_name>)

Vg and Vd are data sets that contain the bias conditions where the linear equivalent circuit is computed. The desired equivalent circuit element name is supplied in the third parameter as a text string. Equivalent circuit element names are: cgs, cgd, cds, ris, rid, gm and gds. The conductances gma and gds are AC values and should be compared with those extracted from S-parameter data.

PEL example that returns the computed requested element value.

```
Cgs_data = EEmos1_ckt(Vg, Vd, “cgs”)
Cgd_data = EEmos1_ckt(Vg, Vd, “cgd”)
Cds_data = EEmos1_ckt(Vg, Vd, “cds”)
Ris_data = EEmos1_ckt(Vg, Vd, “ris”)
Rid_data = EEmos1_ckt(Vg, Vd, “rid”)
Gm_data = EEmos1_ckt(Vg, Vd, “gm”)
Tau_data = EEmos1_ckt(Vg, Vd, “tau”)
Gds_data = EEmos1_ckt(Vg, Vd, “gds”)
```

EEmos1_cs_dc_iv This function is obsolete.

Computes the model’s common source bias response.

Usage: EEmos1_cs_dc_iv (Data_port_1, Data_port_2, Mode_port_1, Mode_port_2, response_port)

This function returns a data set containing the bias response at the port specified by the fifth parameter (response_port). The first 2 parameters are data sets that contain the bias conditions forced at the respective ports. The next 2 parameters are strings that indicate whether current “I” or voltage “V” is being forced. The fifth parameter is an index that specifies which port’s (1 or 2) bias response will be contained in the data set returned.

PEL Example:

```
Ids = EEmos1_cs_dc_iv(Vg, Vd, “V”, “V”, 2)
Igs = EEmos1_cs_dc_iv(Vg, Vd, “V”, “V”, 1)
Vds = EEmos1_cs_dc_iv(Vg, Id, “V”, “I”, 2)
Vgs = EEmos1_cs_dc_iv(Ig, Vd, “I”, “V”, 1)
```

EEmos1_lecp This function is obsolete.

Returns the requested linear equivalent circuit parameter value extracted from measured S-parameter data.

Usage: EEmos1_lecp (Vg, Vd, <ckt_par_name>)

This function is used in conjunction with EEmos1_s2ckt() to extract and display linear equivalent circuit parameters from measured S-parameter data. EEmos1_s2ckt does the extraction of linear equivalent circuit parameters from measured S-parameters and stores them internally to ICCAP. EEmos1_lecp retrieves the linear equivalent circuit parameter values. The specific element returned is requested by the string in the third field of the function call. Valid equivalent circuit element names are cgs, cdg, cds, ris, rid, gm, and gds. An error condition will be flagged if a bias condition is specified in EEmos1_lecp that was not in the data stored by a previous call to EEmos1_s2ckt.

PEL example that returns the computed requested element value.

```
Cgs_data = EEmos1_lecp(Vg, Vd, “cgs”)
Cgd_data = EEmos1_lecp(Vg, Vd, “cgd”)
Cds_data = EEmos1_lecp(Vg, Vd, “cds”)
```

```
Ris_data = EEmos1_lecp(Vg, Vd, “ris”)
Rid_data = EEmos1_lecp(Vg, Vd, “rid”)
Gm_data = EEmos1_lecp(Vg, Vd, “gm”)
Tau_data = EEmos1_lecp(Vg, Vd, “tau”)
Gds_data = EEmos1_lecp(Vg, Vd, “gds”)
```

EEmos1_mdl This function is obsolete.

Saves model parameters to a Series IV formatted file.

Usage: EEmos1_mdl(“file_name.txt”)

This function returns no data or result code. Upon execution, an “MDIF” formatted data file containing the existing set of model parameters is written to the current working directory.

PEL example that saves a data file that can be read by Series IV simulators.

```
dummy_result = EEmos1_mdl(“MRF_901.par”)
```

EEmos1_model_name This function is obsolete.

A utility function that copies the model name into the variable passed in as the argument.

Usage: EEmos1_model_name(variable):

Since PEL only has direct access to the relative path name of local transforms and variables, this function parses out the model’s “root” name and copies it as a string to the variable specified as the argument. After execution, the argument variable will contain a string containing the model name.

Note: This function can be used with any model file; it is not restricted to EEmos1.

PEL example that copies the model name into the variable “MyName.”

```
dummy_result = EEmos1_modle_name(MyName)
```

EEmos1_package This function is obsolete.

A utility function that can either “embed or de-embed” the effects of a package from S-parameter data provided as input. The resultant set of S-parameters is returned as a data set with the same frequency and bias conditions as the input S-parameter data set.

Usage: Efet3_package(S_parameter_data_set, embed/deembed_flag, Rg, Rd, Rs, Lg, Ld, Ls, Cxgs, Cxds, Cxgd, Z0_gate, length, effective_velocity, Z0_drain, length, effective_velocity)

This function either embeds or de-embeds the S-parameters provided as input. The package topology used here is a very simple series shunt representation of a component’s package. The elements represented in the argument list work from the intrinsic device to the outside wall of the package. The bond wire and contact resistances are represented by the arguments: Rg, Rd, Rs, Lg, Ld, Ls. The arguments Rg and Lg are the input port’s (gate) series inductance and resistance. Rs and Ls are the common lead’s inductance and resistance. Rd and Ld are the output lead’s contact resistance and bond inductance.

Three shunt capacitances are next and represent stray capacitance of the package. Cxgs is connected from the outside of the series impedances from gate-to-source nodes just described. Cxgd is connected from the outside of the series impedance from the gate to drain nodes just described. Cxds is connected from the outside of the series impedance from drain to source as just described.

The final series elements of the package model are transmission lines. Z0_gate, length and effective velocity describe the input transmission line connected at the gate terminal of the package to the modified gate node just outlined above. Z0_drain, length and effective velocity describe the output transmission line connected at the drain

terminal of the package to the modified drain node just outlined above. There is no common lead transmission line in this package model.

Because you must use the same values for each of these arguments in many places in the IC-CAP model file, this function is constructed to use model variables as arguments. First: create 1 variable, in the model variable table, for each of the function arguments (thus making it global to the entire model in use). Then use the variables each time the function is used. In this manner you can ensure that the same values are being used to embed the model as were extracted from measurements.

The first argument is the data set upon which the function will operate. The second argument is a text string or variable containing a text string “embed” or “deembed.” The function will operate on the input data set as indicated by the second argument.

PEL example that de-embeds a package from a measurement:

```
s_intrinsic = EEmos1_package(measured_s, “deembed”, Rin,
Rout, Rcommon, Lin, Lout, Lcommon, Cx_InToCommon, CxInToOut,
CxOutToCommon, Z0_in, L_in, Evel, Z0_out, L_out, Evel)
```

EEmos1_ResCheck This function is obsolete.

Verifies and adjusts variables that are used to control swept measurements.

Usage: EEmos1_ResCheck(Start, Stop, Number_of_Points, resolution)

Each argument of EEmos1_ResCheck is a model variable. These variables are used in DUT/Setups to control measurements. Each type of measurement equipment has resolution limitations. Start, stop, and step size must be within the equipment’s resolution before a measurement can be successful. For example, the HP/Agilent 4142 cannot resolve voltages with greater accuracy than 1 millivolt. There

are several conditions that must be accounted for to guarantee proper control of the measurement equipment in use.

The following sequence of steps should be followed to ensure that equipment limitations are not violated. First, the start value is rounded to a “resolvable” measurement value as specified by the argument “resolution.” The end point is then rounded. The step size is then calculated [step = (stop-start) / points] and rounded to the proper resolution. The end point is then re-computed and adjusted to exactly fit the number of steps requested [stop = start + step * points]. Because of this adjustment, you may see the “stop” point change after this function is called. The last case is where the step size is below the minimum resolution. In this case, the step size is set to the minimum resolution and the starting point is placed that number of points away and the number of points is adjusted. The “resolution” argument is the only value that will not change upon execution of this function.

PEL Example:

```
dummy_result = EEmos1ResCheck(Vstart, Vstop, NumPoints,
                                v_res)
```

EEmos1_s2ckt This function is obsolete.

Converts S-parameters to a table of linear equivalent circuit element values.

Usage: EEmos1_ s2ckt (S_parameter, Frequency, Vg, Vd, Conductance_Frequency, Capacitance_Frequency, Delay_Frequency)

This function returns a data set containing S-parameters computed from a linear equivalent circuit model. Element values for the linear equivalent circuit model are extracted from the input S-parameter data set. The table of element values for the linear equivalent circuit model are stored internally to IC-CAP and can be accessed using EEmos1_lecp(). In this manner, you can both examine how well the linear equivalent circuit model fits measured S-parameter data over frequency and see how the element values behave over bias.

The reason for this 2-step process is that each IC-CAP function can only return a data set of the same type and dimension as the input data set. In the first step (EEmos1_s2ckt) S-parameters are input (over frequency and bias) and a computed set of S-parameters is returned (over frequency and bias). The values of the linear equivalent circuit model extracted are saved in a special internal structure. The second step is to create a DUT/Setup that only sweeps bias, not frequency. The function EEmos1_lecp is then used to access the internal data structure and return the linear equivalent circuit element value requested. The output is then of the same type and array size as the bias range. Element values can then be plotted against bias.

PEL Example:

```
computed_s_parameters = EEmos1_s2ckt(s_data, freq, Vg, Vd,
                                     FG, FC, Ftau)
```

and in another DUT/Setup the next function recalls Cgs saved

```
Cgs_data = EEmos1_lecp(Vg, Vd, “cgs”)
```

EEmos1_spars This function is obsolete.

Computes modeled S-parameters based on the current set of model parameters.

Usage: EEmos1_ spars (measured_S_parameter_data_set, Frequency, Vg, Vd)

Computes the bias-dependent model's intrinsic S-parameters at each bias and frequency specified. The S-parameter data set used as an input is only for the purpose of defining the type and quantity of data this function will supply as an output. Typical use would be comparing the computed set of S-parameters to a set of measured data and using that measured data as the S-parameter data set supplied as input to this function

PEL Example:

```
computed_s_parameters = EEmos1_spars(s_data, freq, Vg, Vd)
```

equation Uses the Parameter Extraction Language interpreter to evaluate an expression and produce a data set. This function is rarely needed, since arithmetic expressions are directly accepted in plot definitions and in the input fields to all of the other functions listed here.

Input Arguments:

Data Sets:	Input (must be IC-CAP recognized data names and not strings in quote marks)
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

exp The arithmetic exponential function; the inverse of the function *log*.

Input Arguments:	
Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

fit_line Calculates and returns a least-squares fitted line. Accepts an X data set followed by a Y data set. If the Y data has multiple curves (steps), fit_line yields multiple fitted lines, 1 for each curve. Use *linfit* for the slope and intercept, rather than a plottable data set. If the OVERRIDE_LIMITS variable is TRUE, the limits can be specified manually with the X_LOW and X_HIGH variables, which can be set from the Plot menu. Note: the imaginary part of the input data sets is disregarded.

Input Arguments:	
Data Sets:	X Data, Y Data
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

floor Returns the largest integer not greater than the given value.

Input Arguments:	
Reals:	Number
Output:	Single real
Automatic Invocation:	On Input Change

FNPort Switching matrix function. Returns the port address for the specified port number. The port address is used by the Connect function. For more information regarding this function, refer to "External Matrix Driver User Functions" on page 166 for more information.

Input Arguments:

Reals or Integers:	Port Number
Output:	Single number with exit status
Automatic Invocation:	None

GAASAC_calc_rc Calculates capacitance and AC parameters from S-parameter measurements. Requires the following setup:

S versus Freq, with V_{ds} and V_{gs} = typical operating values

If S-parameter data from the *parasitic_r_l* setup is supplied as an input, this data is converted to Z-parameters and subtracted before calculating the intrinsic values for Z_{ds}. This function can be used to plot the data that is used for extraction in the *GAASAC_r_and_c* function. Output is a complex array that is controlled by the Mode input. Valid modes are:

GS - RGS in real array, CGS in complex array
GD - RGD, CGD
DS - RDS, CDS
A5 - TAU, A5
G0 - CGS0, CGD0
GM - YGM

Input Arguments:

Data Sets:	F Swp, S Parameters, VG, VD, S Pars RL
Strings/Pars/Vars:	Mode
Output:	Array of complex numbers; size determined by inputs

Automatic Invocation: On Data Set Input Change

GAASAC_calc_rl Calculates inductances and resistances from an S-parameter measurement made at a single bias. Requires the following setup:

S versus Freq, with high V_{gs} and V_{ds} = 0

Determine the bias point by measuring the device with the gate strongly forward biased. Typically, $V_d = V_s = 0$ with V_g positive. Ig should be more than 100 mA/mm, with Id approximately equal to Ig/2 at a typical operating frequency. This function can be used to plot the resistance and inductance data that is used for extraction in the *GAASAC_l_and_r* function. Output is in the form of Z data for the G, D, or S *Node*. If *IG* is specified as an input, the dynamic resistance is subtracted during the calculation of RG. If *Deembed* is TRUE, the bond inductance and pad capacitance are used in the calculation of resistance and inductance.

Input Arguments:

Data Sets:	F Swp, S Parameters, IG
Strings/Pars/Vars:	Deembed, Node
Output:	Array of complex numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

GAASAC_cur Standard extraction for the Curtice GaAs model. Extracts the capacitance and AC parameters from S-parameter measurements. Requires the following setup:

S versus Freq, with V_{ds} and V_{gs} = typical operating values

If the variables *LINEAR_CGS*, *LINEAR_CGD*, or *CONSTANT_TAU* are true, CGS, CGD, or TAU are extracted, respectively. Depending on the device, optimization may be required to tune the parameter values.

Input Arguments:

Data Sets:	Frequency, Gate V, Drain V, S Par Output
Output:	None
Extracts:	LD, LG, LS, RD, RG, RS
Automatic Invocation:	By Extract menu function

GAASAC_l_and_r Standard extraction for the UCB and Curtice GaAs models. Extracts inductances and resistances from an S-parameter measurement made at a single bias. Requires the following setup:

S versus Freq, with high V_{gs} and $V_{ds} = 0$

Determine the bias point by measuring the device with the gate strongly forward biased. Typically, $V_d = V_s = 0$ with V_g positive. Ig should be more than 100 mA/mm, with Id approximately equal to Ig/2 at a typical operating frequency. The frequency can be either constant or swept. The extracted parameter values are averaged over a frequency range specified by the *X_LOW* and *X_HIGH* variables, which can be set from the *Plot* menu. If these variables are not set, the entire frequency range is used. If *IG* is specified as an input, the dynamic resistance is subtracted during the calculation of RG. If *Deembed* is true, the bond inductance and pad capacitance are used in the calculation of resistance and inductance. Optimization can be used to tune the parameter values, but should not typically be required.

Input Arguments:

Data Sets:	Const F Swp, S Parameters, IG
Strings/Pars/Vars:	Deembed
Output:	None
Extracts:	LD, LG, LS, RD, RG, RS
Automatic Invocation:	By Extract menu function

GAASAC_r_and_c Alternate AC extraction for the UCB and Curtice GaAs models. Extracts the capacitance and AC parameters from S-parameter measurements. Requires the following Setup:

S versus Freq, with Vds and Vgs = typical operating values.

The extracted parameter values are averaged over a frequency range specified by the X_LOW and X_HIGH variables, which can be set from the Plot menu. If these variables are not set, the entire frequency range is used. For the Curtice model, if the variables LINEAR_CGS, LINEAR_CGD, or CONSTANT_TAU are TRUE, CGS, CGD, or TAU are extracted, respectively. Also for the Curtice Model, the parameters CGDN, RGDN, and RDS are extracted if they are defined as either parameters or variables. If CGDN is defined, then both CGD and CGDO are set to 0. For the UCB model, CDS is extracted if it is defined as a parameter or variable. For both models, YGM_MAG and YGM_PHASE are extracted if they are defined as variables. If S-parameter data from the parasitic_r_l Setup is supplied as an input, this data is converted to Z- parameters and subtracted before calculating the intrinsic values for Zds. Depending on the device, optimization may be required to tune the parameter values.

Input Arguments:

Data Sets:	F Swp, S Parameters, VG, VD, S Pars RL
Output:	None
Extracts:	Curtice:
	CGSO, CGDO, CDS, RIN, A5
	Optionally - CGS, CGD, TAU, CGDN, RGDN, RDS, YGM_MAG, YGM_PHASE UCB: CGS, CGD
	Optionally - CDS, YGM_MAG, YGM_PHASE

Automatic Invocation: By Extract menu function

GAASCV_cgs_cgd Standard extraction for the UCB GaAs model. Extracts junction capacitances from S-parameter data measured with VGS and VDS held constant. Requires the following Setup:

S versus Freq, with Vds and Vgs = typical operating values.

Optimization can be used to tune the parameter values, but should not typically be required.

Input Arguments:

Data Sets:	Freq Sweep, Const Vgs Sw, Const Vds Sw, S Par Output
Output:	None
Extracts:	CGD, CGS
Automatic Invocation:	By Extract menu function

GAASDC_cur1 Standard extraction for the Curtice GaAs model. Extracts the threshold parameters from DC measurements. Requires the following Setup:

Id versus Vgs, with high Vds.

Depending on the device, optimization may be required to tune the parameter values. The optimization should not include too much of the pinch-off region.

Input Arguments:

Data Sets:	Gate V, Drain V, Drain I
Output:	None
Extracts:	Level 1: VTO Level 2: A0, A1, A2, A3
Automatic Invocation:	By Extract menu function

GAASDC_cur2 Standard extraction for the Curtice GaAs model. Extracts the linear and saturation parameters from DC measurements. Requires the following Setup:

Id versus Vds versus Vgs.

Optimization is typically required to tune the parameter values.

Input Arguments:

Data Sets:	Drain V, Gate V, Drain I
Output:	None
Extracts:	Level 1: BETA, LAMBDA, ALPHA Level 2: BETA, GAMMA
Automatic Invocation:	By Extract menu function

GAASDC_lev1 Standard extraction for the UCB and Curtice GaAs models. Extracts diode (and optionally resistance) parameters from DC measurements. Requires the following Setups:

Ig versus Vg, with Vd = 0 and S floating.

Ig versus Vg, with Vd less than 50 mV.

Ig versus Vg, with Vs = 0 and D floating.

The Vg limits for the diode parameter extraction are automatically selected. If the OVERRIDE_LIMITS variable is TRUE, these limits can be specified manually with the X_LOW and X_HIGH variables, which can be set from the Plot menu. Omit the resistance extraction (useful if resistances were extracted using GAASAC_l_and_r) by specifying only the first Setup of the 3 listed above. Optimization can be used to tune the parameter values, but should not typically be required.

Input Arguments:

Data Sets:	VG (S Flt), IG (S Flt), VG (low Vds), VD (low Vds), ID (low Vds), VG (D Flt), IG (D Flt)
Output:	None
Extracts:	UCB: PB, IS, XN Curtice: VBI, IS, N Optionally: RD, RS
Automatic Invocation:	By Extract menu function

GAASDC_lev2 Standard extraction for the UCB GaAs model. Extracts the drain current parameters from DC measurements. Requires the following setups:

I_d versus V_d versus V_g
I_d versus V_g, with V_d = constant

Depending on the device, the following parameters may require optimization: VTO, BETA, ALPHA, LAMBDA over I_d versus Vd. VTO, BETA, B over I_d versus V_g.

Input Arguments:

Data Sets:	IdVg VG, IdVg VD, IdVg ID, IdVg IG, IdVd VD, IdVd VG, IdVd ID, IdVd IG
Output:	None
Extracts:	VTO, BETA, ALPHA, LAMBDA, B
Automatic Invocation:	By Extract menu function

GAASDC_rd DC RD extraction for the UCB and Curtice GaAs models. Requires the following setup:

V_{sd} versus I_g, with the source floating and the drain grounded

This extraction can be used to extract RD when AC measurements are not available, or to verify the value extracted from the *GAASAC_l_and_r* function.

Input Arguments:

Data Sets:	IG, VS
Output:	None
Extracts:	RD
Automatic Invocation:	By Extract menu function

GAASDC_rs DC RS extraction for the UCB and Curtice GaAs models. Requires the following setup:

V_{ds} versus $I_{g,}$ with the drain floating and the source grounded

This extraction can be used to extract RS when AC measurements are not available, or to verify the value extracted from the *GAASAC_l_and_r* function.

Input Arguments:

Data Sets:	IG, VD
Output:	None
Extracts:	RS
Automatic Invocation:	By Extract menu function

GAASmod_cgd Given the drain, gate, and source voltages, calculates gate-drain capacitance according to the UCB GaAs model.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

GAASmod_cgs Given the drain, gate, and source voltages, calculates gate-source capacitance according to the UCB GaAs model.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

GAASmod_id Given the drain, gate, and source voltages, calculates drain current according to the UCB GaAs model.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

GAASmod_ig Given the drain, gate, and source voltages, calculates gate current according to the UCB GaAs model.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	None

H11corr Produces an input impedance curve corrected for the effects of base to collector feedthrough impedance. The corrected output is used as input to the *RBBcalc* function described below.

Input Arguments:

Data Sets:	FREQ, VB, VC, H11
Output:	Array of complex numbers; size determined by inputs

Automatic Invocation: On Data Set Input Change

HFBJT_linear_elem_extr No documentation available at this time.

HFBJT_linear_ssmod_sim No documentation available at this time.

HFMOD_get_bias_size Finds the number of bias points in a data set. For sweeps that don't include a frequency sweep, this is the same as the total number of points in the dataset.

Usage: HFMOD_get_bias_size(<Dataset name>, <Setup path>)

Input Arguments:

<Dataset name>	Name if dataset to be checked
<Setup path>	Variable containing path of dataset

Example PEL statement:

```
data_size = HFMOD_get_bias_size("s", PATH)
```

HFMOD_get_freq_index Finds the array index of the frequency point nearest to (>=) the specified frequency value.

Usage: HFMOD_get_freq_index(<Setup path>, <Freq value>)

Input Arguments:

<Setup path>	Variable containing path of dataset
<Freq value>	Variable containing frequency value

Example PEL statement:

```
index_freq_cap = HFMOD_get_freq_index(PATH, FREQ_CAP)
```

HFMOD_get_freq_value Finds a specific frequency value, given an index value.

Usage: HFMOD_get_freq_value(<Setup path>, <Freq index>)

Input Arguments:

<Setup path>	Variable containing path of dataset
<Freq index>	Variable containing frequency index

Example PEL statement:

```
freq_cap = HFMOD_get_freq_value(PATH, index_freq_cap)
```

HFMOD_remove_freq_dbl Reduces a matrix of bias and frequency dependent data (type double) down to a bias dependent matrix only.

Usage: HFMOD_remove_freq_dbl(<Input double>, <Dataset name>, <Setup path>)

Input Arguments:

<Input double>	Dummy input matrix (must be dimensioned to desired size of output matrix)
<Dataset name>	Name of dataset to be reduced
<Setup path>	Variable containing path of dataset to be reduced

HFMOD_remove_freq_mat Reduces a complex matrix of bias and frequency dependent 2-port parameters down to a bias dependent matrix only.

Usage: HFMOD_remove_freq_mat(<Input matrix>, <Freq Index>, <Dataset name>, <Setup path>)

Input Arguments:

<Input matrix>	Dummy input matrix (must be dimensioned to desired size of output matrix)
<Freq Index>	Variable containing frequency index of desired frequency point
<Dataset name>	Name of dataset to be reduced
<Setup path>	Variable containing path of dataset to be reduced

Example PEL statement:

```
s_cond = HFMOD_remove_freq_mat(dummy_mat, INDEX_FREQ_CAP,
                               "s", PATH)
```

HFMOS3_capas This function is obsolete.

Extracts the overlap capacitances CGSO and CGDO and the oxide thickness TOX from the capacitance data.

Extracts:	CGDO, CGSO, TOX

HFMOS3_lin_large This function is obsolete.

Standard extraction for the HF MOS Level 3 model. Extracts classical Level 3 parameters, using Id versus Vg data from a large device.

Extracts:	VTO, NSUB, UO, THETA, DELTA, RDS

HFMOS3_lin_narrow This function is obsolete.

Standard extraction for the HF MOS Level 3 model. Extracts Level 3 width parameters, using Id versus Vg data from a narrow device.

Extracts:	WD, DELTA

HFMOS3_lin_short This function is obsolete.

Standard extraction for the HF MOS Level 3 model. Extracts Level 3 length effect parameters, using Id versus Vg data from a short device.

Extracts: XJ, LD, RDS

HFMOS3_modcap This function is obsolete.

Calculates the Gate-Source and Gate-Drain capacitances according to the Meyer model or Bulk-Drain junction capacitance according to the UCB MOS model.

HFMOS3_paras This function is obsolete.

Extracts gate, drain and source parasitic resistances and inductances from the impedance data.

Extracts: RS, RD, RG, LSS, LDD, LGG

HFMOS3_sat_short This function is obsolete.

Standard extraction for the HF MOS Level 3 model. Extracts Level 3 saturation parameters, using Id versus Vd data from a short device.

Extracts: VMAX, KAPPA

HFMOS3_StoC This function is obsolete.

This function calculates capacitance data from S-parameter data, allowing gate-source , gate-drain, and junction capacitances to be calculated from network analyzer measurements. The output of this function can be used in place of actual capacitance data to extract capacitance related parameters.

HFMOS3_StoZ This function is obsolete.

This function calculates impedance data from S-parameter data, allowing gate, drain, and source impedances to be calculated from network analyzer measurements. The output of this function can be used in place of actual impedance data to extract the parasitics parameters.

HFMOS3_sub_large This function is obsolete.

Standard extraction for the HF MOS Level 3 model. Extracts Level 3 subthreshold parameters, using Id versus Vg data from a large device. Initializes ETA for later optimization.

Extracts: NFS, ETA

HFMOS3_total_cap This function is obsolete.

Extracts the total PN junction capacitance parameters from the bottom and sidewall. Requires C-V measurement on 2 different geometries. The first measurement should be on a device in which the bottom capacitance dominates. The second measurement should be on a device in which the sidewall capacitance dominates.

Extracts: CJ, MJ, CJSW, MJSW, PB

HP5250_bias_card HP 5250A Switching Matrix function. Bias-enables all the output ports for the specified card.

Syntax

```
HP5250_bias_card(CardNumber, “CardState”)
```

Where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

“CardState” is the card's state (allowed values are ENABLE/DISABLE or E/D)

HP5250_bias_channel HP 5250A Switching Matrix function. Bias-enables the specified output ports in the channel list. Note that the input ports are ignored since the input port is always the Bias Input Port.

Syntax

```
HP5250_bias_channel (“State”, “Channel list”)
```

Where

“State” is the output port's state (allowed values are ENABLE/DISABLE or E/D)

“Channel list” is the list of channels, known as connection routes. Example channel list: (@10102, 10203, 10305:10307)

HP5250_bias_init HP 5250A Switching Matrix function. Selects the bias port. When using the HP E5255A card, the Input Bias Port is the dedicated bias port; however, for the HP E5252A the Input Bias Port must be selected using this function.

Syntax

```
HP5250_bias_init(CardNumber, InputBiasPort)
```

Where

Card Number specifies the card (allowed values 0-4, 0 = auto configuration mode)

InputBiasPort specifies the input bias port number (allowed values are 1-10)

HP5250_bias_setmode HP 5250A Switching Matrix function. Enables the bias mode for the specified card once Input Bias Port and Enabled Output ports have been specified.

Syntax

```
HP5250_bias_setmode (CardNumber, “BiasMode”)
```

Where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

"BiasMode" sets the bias mode on or off (allowed values are ON/OFF or 1/0)

When Bias Mode is ON, the Input Bias Port is connected to all the Bias Enabled output ports that are not connected to any other input ports. Bias Disabled output ports are never connected to an Input Bias Port when Bias Mode is ON.

- If another input port is disconnected from a bias enabled output port, this port is automatically connected to the Input Bias Port.
- If another input port is connected to a Bias Enabled output port, the output port is automatically disconnected from the Bias Input port.

When Bias Mode is OFF, the Input Bias Port is the same as the other ports.

HP5250_card_config HP 5250A Switching Matrix function. Changes the default configuration for the specified card. When the connection rule is FREE (default mode), each input port can be connected to multiple output ports and each output port can be connected to multiple input ports. When the connection is SINGLE, each input port can be connected to only 1 output. Connection sequence specifies the open/close sequence of the relays when changing from an existing connection to a new connection.

Syntax

```
HP5250_card_config (CardNumber, "ConnRule",
                    "ConnSequence")
```

Where

CardNumber specifies the card (0 for AUTO configuration mode)

"ConnRule" is FREE/SINGLE (default is FREE)

"ConnSequence" is NSEQ/BBM/MBBR (default is BBM)
NSEQ (No SEQuence): Disconnect old route, connect new route.
BBM (Break Before Make): Disconnect old route, wait,

connect new route.
MBBR (Make Before BReak): Connect new route, wait, disconnect old route.

HP5250_compensate_cap HP 5250A Switching Matrix function. Equivalent to IC-CAP C routine for the HP BASIC capacitance compensation routine called Ccompen_5250 supplied with the HP 5250A. It returns a 2 by 1 matrix (2 rows, 1 column) defined as follows:

output.11 represents compensated capacitance data [F].

output.21 represents compensated conductance data [S].

Syntax

```
HP5250_compensate_cap (RawCap, RawCond, Freq,
                       HPTriaxLength, UserTriaxLengthHigh,
                       UserTriaxLengthLow,
                       UserCoaxLengthHigh,
                       UserCoaxLengthLow)
```

Where

RawCap is Input Dataset containing raw capacitance data [F]

RawCond is the Input Dataset containing raw conductance data [S]

Freq is the measured frequency [Hz]

HPTriaxLength is the Triax Cable Length [m]

UserTriaxLengthHigh is the user Triax Cable Length (High) [m]

UserTriaxLengthLow is the user Triax Cable Length (Low) [m]

UserCoaxLengthHigh is the user Coax Cable Length (High) [m]

UserCoaxLengthLow is the user Coax Cable Length (Low) [m]

HP5250_connect HP 5250A Switching Matrix function. Connects or disconnects specified channels. Note that Bias Mode and/or coupling Mode are also taken into account when a channel is closed or opened.

Syntax

```
HP5250_connect (“Action”, “Channel list”)
```

Where

“Action” connects or disconnects channels (allowed values are C and D)

“Channel list” is the list of connection routes to be switched Example: In the list (@10102, 10203:10205), the following channels are connected or disconnected on card 1:

- Input port 1 to output port 2.
- Input port 2 to output port 3, 4, and 5.

HP5250_couple_enable HP 5250A Switching Matrix function. Enables couple port mode. Couple port allows synchronized connection of 2 adjacent input ports to 2 adjacent output ports.

Syntax

```
HP5250_couple_enable (CardNumber, “CoupleState”)
```

Where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

“CoupleState” is the coupled state (allowed values are ON/OFF or 1/0)

HP5250_couple_setup HP 5250A Switching Matrix function. Sets up couple ports for making kelvin connections.

Syntax

```
HP5250_couple_setup (CardNumber, “InputPorts”)
```

Where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

"InputPorts" is the list of coupled ports Example: In the list "1,3,5,7,9" the coupled ports are 1-2, 3-4, 5-6, 7-8, 9-10

HP5250_debug HP 5250A Switching Matrix function. Used only for debugging. When the debug flag is set to 1, all the functions print out all the command strings that are sent to the instruments. Set flag using the values 1 or 0, or use YES or NO.

Syntax

```
HP5250_debug(<flag>)
```

HP5250_disconnect_card HP 5250A Switching Matrix function. Opens all relays or channels in the specified cards.

Syntax

```
HP5250_disconnect_card (CardNumber)
```

Where

CardNumber specifies the card (allowed values 0-4, 0 = auto configuration mode)

HP5250_init HP 5250A Switching Matrix function. Must be run first to initialize the instrument with the address and interface. Using this transform the configuration mode can be set to AUTO. When the instrument is in AUTO configuration mode the same type of card must be installed in the HP 5250 slots from slot 1 continuously. The installed cards are then treated as 1 card (numbered 0).

Syntax

```
HP5250_init (BusAddress, "Interface", "Configuration")
```

Where

BusAddress is interface bus address (default is 22)

"Interface" is interface name (default is hpib)

"Configuration" is AUTO/NORMAL A/N (default is NORMAL)

HP5250_show HP 5250A Switching Matrix function. Has no inputs. Returns to the standard output (screen or file) the following data about the instrument status:

Instrument Name

Instrument Configuration (AUTO/NORMAL).

The following information is output for each card installed in the instrument (card 0 if the instrument is in auto configuration mode):

Connection mode

Connection sequence

Input Bias Port

Enabled Output Bias Ports

Bias Sate (ON/OFF)

Coupled Input Ports (only lower number is listed, e.g., “3,5” means ports 3 and 4 are coupled)

Couple Port Mode (ON/OFF)

Connection Matrix Inputs(10)xOutputs(12,24,36, or48).

HPdiode_C Produces an array of data that contains the high-frequency intrinsic capacitance at measured bias points for the Agilent Root Diode model.

Output:	Array of real numbers; size determined by the setup
Automatic Invocation:	None

HPdiode_C2 Produces an array of data that contains the high-frequency intrinsic capacitance at measured bias points for the Agilent Root Diode model.

Output Array of real numbers; size determined by the setup

HPdiode_I Produces an array of data that contains the current values at measured bias points for the Agilent Root Diode model.

Output Array of real numbers; size determined by the setup

HPdiode_Q Produces an array of data that contains the charge values at measured bias points for the Agilent Root Diode model.

Output Array of real numbers; size determined by the setup

HPdiode_R Produces an array of data that contains the intrinsic resistance at measured bias points for the Agilent Root Diode model.

Output Array of real numbers; size determined by the setup

HPdiode_S11i Produces an array of data that contains the imaginary part of S11 at measured bias points for the Agilent Root Diode model.

Output Array of real numbers; size determined by the setup

HPdiode_S11r Produces an array of data that contains the real part of S11 at measured bias points for the Agilent Root Diode model.

Output Array of real numbers, size determined by the setup

HPdiode_V Produces an array of data that contains the voltage values at measured bias points for the Agilent Root Diode model.

HPdiode_data_acqu Extraction function for acquiring data for the Agilent Root Diode model. Adaptively takes data throughout the safe operating range of the device.

Input Arguments:

Reals or Integers:	Vmax, Vmin, Max step, Min step, Noise level, Eps
Automatic Invocation:	By Extract menu function

HPdiode_fgrt No documentation available at this time

HPdiode_fless No documentation available at this time

HPdiode_iextr No documentation available at this time

HPdiode_mdl Extraction function for generating the Agilent Root Diode model.

Input Arguments:

Reals or Integers:	LowBound V, HighBound V, Extraction f
Extracts:	Generates the model function and look-up table
Automatic Invocation:	By Extract menu function

HPdiode_para_at_f Calculates parasitics at the specified frequency for the Agilent Root Diode model.

Input Arguments:

Reals or Integers:	Extraction f
Extracts:	cac, cag, ccg, R, L_tot

HPdiode_para_f Extracts parasitic elements and writes them to the Para.data file.

Input Arguments:

Data Sets:	Freq, S param, I
Reals or Integers:	Ideality

Output: None

HPdiode_wr Writes the inputs to the Measured.data file.

Input Arguments:

Data Sets: Freq, S param, I, V

HPIB_abort Breaks GPIB communication and resets the bus.

Input Arguments:

Reals or Integers: File descriptor returned from *HPIB_open()*

Output: 0 for success, -1 for error.

Automatic Invocation: None

Example PEL Statement:

```
x = HPIB_abort(file_num)
```

HPIB_clear Sends a Device Clear command to an instrument.

Input Arguments:

Reals or Integers: File descriptor returned from *HPIB_open()*, target GPIB address.

Output: 0 for success, -1 for error.

Automatic Invocation: None

Example PEL Statement:

```
x = HPIB_clear(file_num, 16)
```

HPIB_close Terminates GPIB communication and releases resources.

Input Arguments:

Reals or Integers:	File descriptor returned from *HPIB_open()*.
Output:	0 for success, -1 for error.
Automatic Invocation:	None

Example PEL Statement:

```
x = HPIB_close(file_num)
```

HPIB_command Sends a single GPIB command byte on the bus.

Input Arguments:

Reals or Integers:	File descriptor returned from *HPIB_open()*, command byte.
Output:	0 for success, –1 for error.
Automatic Invocation:	None

Example PEL Statement:

```
x = HPIB_command(file_num, 20) ! DCL
```

HPIB_eoi Enables or disables if eoi is sent with last byte transmitted.

Usage:	HPIB_eio(EID,eoiFlag)
Input Arguments:	
EID	Specifies the descriptor returned from HPIB_open()
eoiFlag	0 for disable, 1 for enable
Output:	0 for success, –1 for error

HPIB_fwrite Formatted write to GPIB. Writes a variety of formats to the designated instrument.

Usage:	HPIB_fwrite(EID,Address,numBytes, numericalData,convertChar)
Input Arguments:	
EID	Specifies the descriptor returned from HPIB_open()
Address	Specifies the address of the instrument
numBytes	Specifies how many bytes to read from the bus
numericalData	Specifies the number to be written out
convertChar	Specifies how to interpret the bytes as follows: "F" Must request numBytes=4 or numBytes=8 Numerical data will be converted to a single or double precision number and sent across the bus. "I" Must request numBytes=2 or numBytes=4 Numerical data will be converted to a 2's complement number of the specified size and sent across the bus.
Output:	0 for success, –1 for error

HPIB_open Initiates GPIB communication and reserves resources. Instrument control through GPIB should use this function family to be portable across platforms. Defined in *userc_io.c*.

Input Arguments:	
Reals or Integers:	Interface file name. Refer to Measurement chapter.
Output:	File descriptor.

Automatic Invocation: None

Example PEL Statement:

```
file_num = HPIB_open("hpib") ! for s700
file_num = HPIB_open("/dev/gpib0") ! for Sun
```

HPIB_read Reads a variety of formats from the designated instrument.

Usage: HPIB_read(EID,Address,numBytes,Format,Variable)

Input Arguments:

EID	Specifies the descriptor returned from HPIB_open()
Address	Specifies the address of the instrument
numBytes	Specifies how many bytes to read from the bus
Format	Specifies how to interpret the bytes as follows: "A" Return an ASCII string less than or equal to numBytes in length (depending on EOI and Null characters read.) Allow for a terminator in your numBytes length, but this terminator will be stripped from the return. "F" Must request numBytes=4 or numBytes=8 Result will be these bytes interpreted as a normal ordered single or double precision number. "I" Must request numBytes=2 or numBytes=4 Result will be these bytes interpreted as a normal ordered 2's complement integer.

"C" Must request numBytes=1. Result will be this byte interpreted as a normal ordered unsigned integer.

"H" Interprets a string of characters as a hexadecimal number and outputs the decimal equivalent. NumBytes may be any length. Hexadecimal interpretation will continue until a non hexadecimal character or NULL byte is encountered. hexadecimal character set [0-9, a-f, A-F].

"O" Interprets a string of characters as an octal number and outputs the decimal equivalent. NumBytes may be any length. Octal interpretation will continue until a non-octal character or NULL byte is encountered. octal character set [0-7].

Variable — Specifies the name of a variable in a variable table will receive the read data.

Output: — 0 for success, –1 for error

HPIB_read_reals This function was obsoleted and replaced by "HPIB_read" on page 532.

Reads multiple real numbers from a designated instrument.

Input Arguments:

Reals or Integers: — File descriptor returned from *HPIB_open()*, target GPIB address, an optional *scanf()* format to pick up a real number. If the format is blank, "%lf" is used.

Output: — Array of real numbers.

Automatic Invocation: None

Example PEL Statement:

```
x = HPIB_read_reals(file_num, 16, "%lf\n")
```

HPIB_readnum This function was obsoleted and replaced by "HPIB_read" on page 532.

Reads a single real number from a designated instrument.

Input Arguments:

Reals or Integers:	File descriptor returned from *HPIB_open()*, target GPIB address, an optional *scanf()* format to pick up a real number. If the format is blank, "%lf" is used.
Output:	a real number (the value 9.99998E+37 means an error occurred).

Automatic Invocation: None

Example PEL Statement:

```
data = HPIB_readnum(file_num, 16, "")
```

HPIB_readstr This function was obsoleted and replaced by "HPIB_read" on page 532.

Reads a single character string from a designated instrument.

Input Arguments:

Reals or Integers:	File descriptor returned from *HPIB_open()*, target GPIB address, an optional *scanf()* format to pick up a real number, a variable name that receives the character string. If the format is blank, "%[^\r\n]*" is used to exclude CR/LF.
Output:	0 for success, -1 for error.

Automatic Invocation: None

Example PEL Statement:

```
x = HPIB_readstr(file_num, 16, "%s\n", "IC-CAP_variable")
```

HPIB_spoll Reads a status byte from a designated instrument.

Input Arguments:

Reals or Integers: File descriptor returned from *HPIB_open()*, target GPIB address.

Output: status byte (real number)

Automatic Invocation: None

Example PEL Statement:

```
status = HPIB_spoll(file_num, 16)
```

HPIB_srq Tests if SRQ line of the bus is True or False.

Input Arguments:

Reals or Integers: File descriptor returned from *HPIB_open()*.

Output: 1 for True, 0 for False, –1 for error

Automatic Invocation: None

Example PEL Statement:

```
srq = HPIB_srq(file_num)
```

HPIB_timeout Sets the GPIB timeout.

Input Arguments:

Reals or Integers: File descriptor returned from *HPIB_open()*, timeout in seconds.

Output: 0 for success, –1 for error

Automatic Invocation: None

Example PEL Statement:

```
x = HPIB_timeout(file_num, 10) ! timeout on 10 sec
```

HPIB_write This function was obsoleted and replaced by "HPIB_fwrite" on page 530.

Sends a character string to a designated instrument.

Input Arguments:

Reals or Integers:	File descriptor returned from *HPIB_open()*, target GPIB address, a character string to be sent that allows normal C escapes.
Output:	0 for success, –1 for error
Automatic Invocation:	None

Example PEL Statement:

```
x = HPIB_write(file_num, 16, "*IDN?\n")
```

HPMOS_process_pars Allows specification of initial values for the Agilent MOS process related parameters LD, RS, RSH, TOX, WD, and XJ. The drain resistance RD is set equal to the specified value of RS.

Input Arguments:

Data Sets:	Lateral Diffusion, Source Resistance, Sheet Resistance, Oxide Thickness, Width Reduction
Output:	None
Extracts:	(not applicable)
Automatic Invocation:	By Extract menu function

HPMOSDC_lin_large Standard extraction for the Agilent MOS model. Extracts classical parameters using I_d versus V_g measured on a large device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	VTO, NSUB, UO, VNORM
Automatic Invocation:	By Extract menu function

HPMOSDC_lin_narrow Standard extraction for the Agilent MOS model. Extracts width effect parameters using I_d versus V_g measured on a narrow device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	WD, VWFF, WFF
Automatic Invocation:	By Extract menu function

HPMOSDC_lin_short Standard extraction for the Agilent MOS model. Extracts length effect parameters using I_d versus V_g measured on a short device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	LD, VDFF, LFF
Automatic Invocation:	By Extract menu function

HPMOSDC_sat_short Standard extraction for the Agilent MOS model. Extracts saturation parameters using I_d versus V_d measured on a short device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I

Output:	None
Extracts:	ETRA, ECRIT, DESAT
Automatic Invocation:	By Extract menu function

HPRoot_data_acqu Extraction function for acquiring data for the Agilent Root model. Adaptively takes data throughout the safe operating range of the device.

Input Arguments:	None
Output:	None
Automatic Invocation:	By Extract menu function

HPRoot_FET Extraction function for generating the Agilent Root FET model.

Input Arguments:	None
Output:	None
Extracts:	Generates the model functions and look-up table.
Automatic Invocation:	By Extract menu function

HPRoot_fet_acqu Extraction function for acquiring data for the Agilent Root FET model. Adaptively takes data throughout the safe operating range of the device.

Input Arguments:	
Reals or Integers:	Power level, I_Brk, I_Fwd, Min Vd, Max Vd, Min Vg, Max Vg, Min step, Max step, Vp, Delta, Vdiode. Eps, Noise thresh, SMU Compl
Output:	None
Automatic Invocation:	By Extract menu function

HPRoot_FET_t Extraction function for generating the Agilent Root FET model.

Input Arguments:	
Reals or Integers:	vd_start, vg_start, t_dispersion
Extracts:	Generates the model function and look-up table
Automatic Invocation:	By Extract menu function

HPRoot_Id Produces array of data that contains the drain current values at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Idh Produces array of data that contains the high frequency current values at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Ig Produces array of data that contains the gate current values at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup

Automatic Invocation: None

HPRoot_initial Initializes plots displayed with the Agilent Root FET model.

Input Arguments: None

Output: None

Automatic Invocation: By Extract menu function

HPRoot_mos_acqu Extraction function for acquiring data for the Agilent Root MOSFET model. Adaptively takes data throughout the safe operating range of the device.

Input Arguments:

Reals or Integers: Power level, I Breakdown, Min Vd, Max Vd, Min Vg, Max Vg, Min step, Max step, Vth, Delta, Eps, Noise thresh, SMU Compl

Automatic Invocation: By Extract menu function

HPRoot_mos_para Calculates Z matrix from S parameter input and extracts the parasitic elements for the Agilent Root MOS model.

Input Arguments:

Data Sets: S param, Freq

Strings/Pars/Vars: Mode (Z / EXTR)

Output: Matrix array, size determined by inputs

HPRoot_MOSFET Extraction function for generating the Agilent Root FET model.

Input Arguments:	
Reals or Integers:	vd_start, vg_start, t_dispersion
Extracts:	Generates the model function and look-up table
Automatic Invocation:	By Extract menu function

HPRoot_n Extracts the ideality parameter for the Agilent Root FET and Agilent Root Diode models.

Input Arguments:	
Data Sets:	V, N array
Reals or Integers:	LowBound V, HighBound V, Max
Output:	None
Extracts:	N
Automatic Invocation:	None

HPRoot_parasitic Measures the parasitic elements of a device for the Agilent Root FET model.

Input Arguments:	None
Output:	None
Extracts:	The parasitic resistors Rs, Rd, and Rg, and the parasitic inductors Ls_tot, Ld_tot, and Lg_tot.
Automatic Invocation:	By Extract menu function

HPRoot_para_cal Calculates the parasitic elements of a device for the Agilent Root FET and Agilent Root MOS models.

Input Arguments:	
Strings/Pars/Vars:	Mode (Mesfet / Mosfet)
Extracts:	Rg, Rs, Rd, Lg_tot, Ls_tot, Ld_tot
Automatic Invocation:	None

HPRoot_Qd Produces array of data that contains the drain charge values at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Qg Produces array of data that contains the gate charge values at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Vd Produces array of data that contains the drain voltage values of the bias distribution of the whole operating range of the device for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Vg Produces array of data that contains the gate voltage values of the bias distribution of the whole operating range of the device for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_wr Reads measured parasitic data and extracted frequency and calculates parasitic resistances, inductances and computes the intrinsic matrix Zp and Yp for linear AC de-embedding.

Input Arguments:	
Data Sets:	Freq, S param, IG, ID, VG, VD
trings/Pars/Vars:	S Mode (s / p)

HPRoot_Y11i Produces array of data that contains the imaginary part of Y_{11} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Y11r Produces array of data that contains the real part of Y_{11} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup

Automatic Invocation: None

HPRoot_Y12i Produces array of data that contains the imaginary part of Y_{12} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Y12r Produces array of data that contains the real part of Y_{12} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Y21i Produces array of data that contains the imaginary part of Y_{21} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Y21r Produces array of data that contains the real part of Y_{21} at measured bias points for Agilent Root FET model.

Input Arguments:	None

Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Y22i Produces array of data that contains the imaginary part of Y_{22} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPRoot_Y22r Produces array of data that contains the real part of Y_{22} at measured bias points for Agilent Root FET model.

Input Arguments:	None
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	None

HPTFT_param This function is obsolete.

The dielectric constant of oxide film in the Agilent A-Si:H TFT model is calculated.

Input Arguments:	
Data Sets:	EPSFM
Output:	The value of EPSFM
Automatic Invocation:	None

HPTFTCV_model_cgd This function is obsolete.

Agilent A-Si:H TFT Gate to Drain Capacitance model. Calculates Cgd from voltages.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Gate to Drain C
Automatic Invocation:	None

HPTFTCV_model_cgs This function is obsolete.

Agilent A-Si:H TFT Gate to Source Capacitance model. Calculates Cgs from voltages.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Gate to Source C
Automatic Invocation:	None

HPTFTDC_model_id This function is obsolete.

Agilent A-Si:H TFT DC model. Calculates Id from voltages.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V
Output:	Drain I
Automatic Invocation:	None

HPTFTDC_lin This function is obsolete.

Standard extraction for the Agilent a-Si TFT model. Extracts linear region parameters using I_d versus V_g measured on a-Si TFT device.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V, Drain I
Output:	None
Extracts:	VTO, UO, PHI, THETA, NFS, GO
Automatic Invocation:	By Extract menu function

HPTFTDC_sat This function is obsolete.

Standard extraction for the Agilent A-Si:H TFT model. Extracts saturation region parameters using I_d versus V_d measured on a-Si:H TFT device.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V, Drain I
Output:	None
Extracts:	VMAX, ETA
Automatic Invocation:	By Extract menu function

icdb_add_comment Writes an arbitrary comment string to the opened file.

Syntax

```
x=icdb_add_comment(strVal)
```

Where

strVal is an arbitrary string.

The return value (x) is undefined.

icdb_close Closes a file that has been opened with icdb_open.

Syntax

```
x=icdb_close()
```

Where

The return value (x) is not defined.

icdb_export_data Exports the measured or simulated data from the specified setup to the opened file. Header information containing current information about the values of the registered sweep parameters is automatically appended to the file.

Syntax

```
x=icdb_export_data(setupName,dataType)
```

Where

setupName	is a string giving a proper path to the setup that contains data to export.
dataType	exports simulated data if dataType is "S". Exports measured data for any other value, but "M" recommended.

The return value (x) is undefined.

icdb_get_sweep_value Returns the current value of the specified user sweep at any point in the export loop.

Syntax

```
curVal=icdb_get_sweep_value(index,swpName)
```

Where

index	is the point number requested
swpName	is the name of the registered sweep

icdb_open Opens a file for exporting measured data in IC-CAP's data management file format (.mdm).

Syntax

```
x=icdb_open(filename)
```

Where

filename	is a string pointing at the MDM file to be opened.

The return value (x) is not defined.

icdb_register_con_sweep Creates a CON type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdb_register_lin_sweep(conValue,swpName)
```

Where

conValue	is the constant value to use for this con sweep
swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in

icdb_register_lin_sweep Creates a LIN type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdb_register_lin_sweep(swpOrder,start,stop,
numSwpPts,swpName)
```

Where

swpOrder	is the sweep order for the registered sweep
start	is the start value for the linear sweep
stop	is the stopping value for the linear sweep
numSwpPts	is the number of points for this sweep
swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in

icdb_register_list_sweep Creates a LIST type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdb_register_list_sweep(swpOrder,swpName,
arrayName)
```

Where

swpOrder	is the sweep order for the registered sweep
swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in
arrayName	is a string naming a variable in a Variable table that has been set to an ICCAP_ARRAY[ ]. This array declares the points that will be used for the list sweep.

icdb_register_lsync_sweep Creates an LSYNC type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all registered sweeps.

Syntax

```
numPts=icdb_register_list_sweep(swpName,masterSweepName,
arrayName)
```

Where

swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in.
masterSweepName	is the name of a previously registered sweep to which this sweep will be synchronized.

arrayName	is a string naming a variable in a Variable table that has been set to an ICCAP_ARRAY[ ]. This array declares the points that will be used for the list sweep. This array should have the same number of points as the already registered Master Sweep.

icdbf_add_comment Writes an arbitrary comment string to the opened file.

Syntax

```
x=icdbf_add_comment(fNum,strVal)
```

Where

fNum	is the number returned from an icdbf_open() call.
strVal	is an arbitrary string.

The return value (x) is undefined.

icdbf_close Closes a file that has been opened with icdbf_open.

Syntax

```
x=icdbf_close(fNum)
```

Where

fNum	is the number returned from an icdbf_open() call.

The return value (x) is not defined.

icdbf_export_data Exports the measured or simulated data from the specified setup to the opened file. Header information containing current information about the values of the registered sweep parameters is automatically appended to the file.

Syntax

```
x=icdbf_export_data(fNum,setupName,dataType)
```

Where

fNum	is the number returned from an icdbf_open() call.
setupName	is a string giving a proper path to the setup that contains data to export.
dataType	exports simulated data if dataType is "S". Exports measured data for any other value, but "M" recommended.

The return value (x) is undefined.

icdbf_get_sweep_value Returns the current value of the specified user sweep at any point in the export loop.

Syntax

```
curVal=icdbf_get_sweep_value(fNum,index,swpName)
```

Where

fNum	is the number returned from an icdbf_open() call.
index	is the point number requested
swpName	is the name of the registered sweep

icdbf_open Opens a file for exporting measured data in IC-CAP's data management file format (.mdm).

Syntax

```
fNum=icdbf_open(filename)
```

Where

filename	is a string pointing at the MDM file to be opened.

The return value (fNum) is a unique number associated with this file. This number is valid during the current run of PEL or until icdbf_close is called.

icdbf_register_con_sweep Creates a CON type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdbf_register_lin_sweep(fNum,conValue,swpName)
```

Where

fNum	is the number returned from an icdbf_open() call.
conValue	is the constant value to use for this con sweep
swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in

icdbf_register_lin_sweep Creates a LIN type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdbf_register_lin_sweep(fNum,swpOrder,start,stop,
numSwpPts,swpName)
```

Where

fNum	is the number returned from an icdbf_open() call.
swpOrder	is the sweep order for the registered sweep
start	is the start value for the linear sweep
stop	is the stopping value for the linear sweep
numSwpPts	is the number of points for this sweep

swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in

icdbf_register_list_sweep Creates a LIST type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdb_register_list_sweep(fNum,swpOrder,swpName,arr
ayName)
```

Where

fNum	is the number returned from an icdbf_open() call.
swpOrder	is the sweep order for the registered sweep
swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in
arrayName	is a string naming a variable in a Variable table that has been set to an ICCAP_ARRAY[ ]. This array declares the points that will be used for the list sweep.

icdbf_register_lsync_sweep Creates an LSYNC type sweep of an arbitrary parameter in the exported file. Intended primarily to create sweeps of parameters that cannot be swept during a measurement. Returns the total number of points in all the registered sweeps.

Syntax

```
numPts=icdbf_register_list_sweep(fNum,swpName,
masterSweepName,arrayName)
```

Where

fNum	is the number returned from an icdbf_open() call.
swpName	is the name of the 'User Input' as it will appear in the MDM file, or how it will be referenced when reading the MDM back in.
masterSweepName	is the name of a previously registered sweep to which this sweep will be synchronized.
arrayName	is a string naming a variable in a Variable table that has been set to an ICCAP_ARRAY[ ]. This array declares the points that will be used for the list sweep. This array should have the same number of points as the already registered Master Sweep.

ICMSarray Returns an array result from an IC-CAP Macro algorithm to the IC-MS result array during test execution. This function is used internally by IC-MS and should never be called directly by the user.

Input Arguments:	
Data Sets:	Array Result
Reals or Integers:	Array Size, Result Data Index
Output:	None
Automatic Invocation:	None

ICMSchar Returns a single character result from an IC-CAP Macro algorithm to the IC-MS result array during test execution. This function is used internally by IC-MS and should never be called directly by the user.

Input Arguments:	
Reals or Integers:	Result Data Index

Strings/Pars/Vars: Character Result

Output: None

Automatic Invocation: None

ICMSint Returns an integer result from an IC-CAP Macro algorithm to the IC-MS result array during test execution. This function is used internally by IC-MS and should never be called directly by the user.

Input Arguments:

Reals or Integers: Integer Result, Result Data Index

Output: None

Automatic Invocation: None

ICMSpin Used in an IC-CAP Macro to determine the matrix connections of the device under test. *ICMSpin* returns the matrix pin number that corresponds to a specified terminal index on the device. This function only returns valid data when IC-MS test execution is running. Refer to the *IC-MS User's Manual* for more information on using *ICMSpin*.

Input Arguments:

Reals or Integers: Terminal Index

Output: Matrix pin number corresponding to the specified device terminal index

Automatic Invocation: None

Example PEL Statement:

```
pin_num = ICMSpin(1)
```

ICMSreal Returns a floating point result from an IC-CAP Macro algorithm to the IC-MS result array during test execution. This function is used internally by IC-MS and should never be called directly by the user.

Input Arguments:

Reals or Integers:	Real Result, Result Data Index
Output:	None
Automatic Invocation:	None

ICMSstr Returns a character string result from an IC-CAP Macro algorithm to the IC-MS result array during test execution. This function is used internally by IC-MS and should never be called directly by the user.

Input Arguments:

Result Data Index:	String Result
Output:	None
Automatic Invocation:	None

icstat_activate Activates a deactivated row or column in the PARAMETERS spreadsheet.

Synopsis:	icstat_activate(<Number>, <Mode>)

Arguments:

Number:	Row or column number to be activated
Mode:	“ROW” or “COLUMN”

Example:

```
retVal = icstat_activate(4, "ROW")
return
```

icstat_analysis Emulates the Analysis command on the Analysis menu. This function generates the “active data” that is, data devoid of the attribute, deactivated, filtered and constant values column. Displays the results in the ANALYSIS spreadsheet.

Synopsis:	icstat_analysis()

Arguments: NONE

Example:

```
retVal = icstat_analysis()
return
```

icstat_attribute_2_parameter Changes the Attribute column to a Parameters column in the PARAMETERS spreadsheet.

Synopsis: icstat_attribute_2_parameter (<Number>)

Arguments: Number: attribute column number to be changed to parameter type

Example:

```
retVal = icstat_attribute_2_parameter(4)
return
```

icstat_clear Clears rows or columns in the PARAMETERS spreadsheet.

Synopsis: icstat_clear(<Start>, <Number>, <Mode>)

Arguments:

Start Row/Column number	Row or column from which to clear
Number of rows/columns	Number of rows/columns to be cleared
Mode:	“ROW” or “COLUMN”

Example (clears 4 rows from the 4th row onward):

```
retVal = icstat_clear(4, 4, "ROW")
return
```

icstat_close_sdf_file Closes the SDF file.

Synopsis: icstat_close_sdf_file(<Filename>)

Arguments:

Filename: Name of the SDF file to close.

Example:

```
retVal = icstat_close_sdf_file
("/tmp/examples/icstat/bsim3.sdf")
return
```

icstat_correlation Emulates the Correlation command on the Analysis menu. This function generates the correlation matrix from the data in the PARAMETERS spreadsheet. Displays the results in the CORRELATION spreadsheet.

Synopsis: icstat_correlation()

Argument: NONE

Example:

```
retVal = icstat_correlation()
return
```

icstat_deactivate Deactivates an activated row or column in the PARAMETERS spreadsheet.

Synopsis: icstat_deactivate(<Number>, <Mode>)

Input Arguments:

Number: Row or column number to be deactivated

Mode: “ROW” or “COLUMN”

Example:

```
retVal = icstat_deactivate(4, "ROW")
return
```

icstat_delete Deletes rows or columns in the PARAMETERS spreadsheet.

Synopsis: icstat_delete(<Start>, <Number>, <Mode>)

Arguments:

Start Row/Column number	Row or column from which to delete
Number of rows/columns	Number of rows/columns to be deleted
Mode:	"ROW" or "COLUMN"

Example (deletes 4 rows from the 4th row onward):

```
retVal = icstat_delete(4, 4, "ROW")
return
```

icstat_equations Emulates the Equations command on the Analysis menu. This function either generates the equations from the factors or the parameters. The results are displayed in the respective spreadsheets: FACTOR EQUATIONS or PARAMETER EQUATIONS.

Synopsis:	icstat_equations(<Type>)
Arguments:	
Type:	Either FACTORS or DOMINANT

Example:

```
retVal = icstat_equations("FACTORS")
return
```

icstat_exit Exits the Statistical Analysis program.

Synopsis:	icstat_exit()
Arguments:	None

Example:

```
retVal = icstat_exit()
return
```

icstat_factor_analysis Emulates the Factor Analysis command on the Analysis menu. This function performs the factor analysis. The results are displayed in the FACTOR LOADINGS and PARAMETER VARIANCE spreadsheets.

Synopsis:	icstat_factor_analysis(<Number-of-factors>, <Method-index>, <Rotation-Index>, <Maximum Iterations>, <Maximum Steps>, <Convergence Iteration>, <Convergence - 2nd derivative>
Arguments:	
Number of factors:	Number of factors
Method Index:	0 = Principal Component 1 = Principal Factor 2 = Unweighted Least Squares
Rotation Index:	0 = Varimax 1 = Quartimax 2 = Equamax 3 = None
Maximum Iterations:	Maximum number of iterations (default = 30)
Maximum Steps:	Maximum number of steps (default = 8)
Convergence Iteration:	Convergence criterion iterations (default = 0.0001)
Convergence 2nd derivative	Convergence criterion 2nd derivative (default = 0.1)

Example:

```
retVal = icstat_factor_analysis(8, 0, 0, 30, 8, 0.0001,
                                0.1)
return
```

icstat_from_partable Updates the PARAMETERS spreadsheet with values from the Parameters table. If a particular spreadsheet parameter is not found in the Parameters table or the Parameters table parameter is not found in the spreadsheet, then the value is not updated.

Synopsis:	icstat_from_partable(<Number>, <Path>, <From Parameter Table>)

Arguments:

Row Number:	Row number to get the data from
Path:	The name of the model or DUT from which you want to get parameters. Specify <“model_name”> to get parameters from the Model Parameters table; specify <“model_name/DUT_name”> to get parameters from the DUT Parameters table. (To specify the current DUT, “.” is sufficient.)
From:	Specify 1 of the following parameter tables from which to get the data: “MODEL PARAMETERS”, “DUT PARAMETERS“ If left blank, “MODEL PARAMETERS” is used.

Example:

```
retVal = icstat_from_partable(2, "/CGaas1", "MODEL
                                PARAMETERS")
return
```

icstat_get_attribute_columns Returns an array of attribute column numbers in the PARAMETERS spreadsheet.

Synopsis:	icstat_get_attribute_columns(<input -array>)

Arguments:

Input:	Array containing the values to be returned

Example:

```
arrSize = icstat_num_attributes()
          complex colArr[arrSize]
retArr = icstat_get_attribute_columns(colArr)
PRINT retArr
```

icstat_get_cell Returns the values in the cell. If the cell contains text, a 0 is returned. Note: To get cells with text, use the icstat_get_text_cell function. To get values from a large number of cells, use icstat_get_column or icstat_get_row.

Synopsis:	icstat_get_cell(<row-number>, <column-number>, <Spreadsheet-name>)
Arguments:	
Row Number:	Integer
Column Number:	Integer
Spreadsheet Name:	One of the Spreadsheet Names
Spreadsheet Names:	PARAMETERS, ANALYSIS, STATSUMM, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS, PARAMETER EQUATIONS, PARAMETRIC, NON PARAMETRIC

Example:

```
rCell = icstat_get_cell(8, 8, "PARAMETERS")
PRINT rCell
return
```

icstat_get_column Returns the values in the column. If the cell contains text, a 0 is returned. Typically the first column for any spreadsheet is of string type. For the PARAMETERS spreadsheet, the values returned include the deactivated and filtered cells.

Synopsis:	icstat_get_column(<Input-array>, <Column number>, <Spreadsheet Name>)
Arguments:	
Input:	Array for the returned value
Column Number:	Integer
Spreadsheet Name:	One of the Spreadsheet Names

Spreadsheet Names: PARAMETERS, ANALYSIS, STATSUMM, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS, PARAMETER EQUATIONS, PARAMETRIC, NON PARAMETRIC

Example:

```
arrSize = icstat_num_rows("PARAMETERS")
          complex colArr[arrSize]
retArr = icstat_get_column(colArr, 7, "PARAMETERS")
PRINT retArr
```

icstat_get_deactivated Returns an array of deactivated rows or columns in the PARAMETERS spreadsheet.

Synopsis: icstat_get_deactivated(<input-array>, <Mode>)

Arguments:

Input: Array containing the values to be returned

Mode: “ROW” or “COLUMN”

Example:

```
arrSize = icstat_num_deactivated("ROW")
          complex rowArr[arrSize]
retArr = icstat_get_deactivated(rowArr, "ROW")
PRINT retArr
```

icstat_get_filtered_rows Returns an array of filtered rows in the PARAMETERS spreadsheet.

Synopsis: icstat_get_filtered_rows (<input-array>)

Arguments:

Input: Array containing the values to be returned

Example:

```
arrSize = icstat_num_filtered()
          complex rowArr[arrSize]
retArr = icstat_get_filtered_rows(rowArr)
PRINT retArr
```

icstat_get_row Returns the values in the row. If any cells contain text, a 0 is returned. Typically the first column for any spreadsheet contain labels, that is, text. For the PARAMETERS spreadsheet, the first several columns could be attribute parameters that is, text. The function excludes the cells in these columns, and returns only real values.

Synopsis:	icstat_get_row(<Input-array>, <Number>, <Spreadsheet Name>)
Arguments:	
Input:	Array for the returned value
Row Number	Integer
Spreadsheet Name:	One of the Spreadsheet Names
Spreadsheet Names:	PARAMETERS, ANALYSIS, STATSUMM, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS, PARAMETER EQUATIONS, PARAMETRIC, NON PARAMETRIC

Example:

```
iNumAttribs = icstat_num_attributes()
iNumCols = icstat_num_columns("PARAMETERS")
iNumCells = iNumCols - iNumAttribs
            complex rowArr[iNumCells]
retArr = icstat_get_row(rowArr, 4, "PARAMETERS")
PRINT retArr
```

icstat_get_text_cell Gets the text in the specified cell and sets the referenced variable with the text.

Synopsis:	icstat_get_text_cell(<Row-Number>, <Column-Number>, <Spreadsheet Name>, <Variable Name>)

Arguments:

Row Number	Integer
Column Number:	Integer
Spreadsheet Name:	One of the Spreadsheet Names
Variable Name:	Variable name from the variable table
Spreadsheet Names:	PARAMETERS, ANALYSIS, STATSUMM, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS, PARAMETER EQUATIONS, PARAMETRIC, NON PARAMETRIC

Example:

```
sString = "Hi, I am a string"
dummy = icstat_set_text_cell(2, 1, sString)
dummy = icstat_get_text_cell(2, 2, "PARAMETERS",
"CELLVAL")
PRINT CELLVAL
return
```

icstat_insert Insert rows or columns in the PARAMETERS spreadsheet.

Synopsis:	icstat_insert(<Start>, <Number>, <Mode>)
Arguments:	
Start Row/Column number	Row or column from which to insert
Number of rows/columns	Number of rows/columns to be inserted
Mode	“ROW” or “COLUMN”

Example (inserts 4 rows from the 4th row onward):

```
retVal = icstat_insert(4, 4, "ROW")
return
```

icstat_nonparametric_models Emulates the non-parametric analysis function.

Synopsis: icstat_nonparametric_models(<Boundary Points>, <% Enclosed>, <Diversity Oversampling>, <Density Estimator %>, <Distance Metric>)

Arguments:

Number of Boundary Points:	Number of boundary models (integer)
Percent Enclosed:	Integer
Diversity Oversampling:	Real number
Density Estimator %:	Integer
Distance Metric:	“EUCLIDEAN” or “L_1” or “L_INFINITY”

Example:

```
retVal = icstat_open()
retVal = icstat_open_sdf_file
         ("/tmp/examples/icstat/bsim3.sdf")
retVal = icstat_nonparametric_models(8, 80, 2, 98,
"EUCLIDEAN")
return
```

icstat_num_attributes Returns the number of attribute columns in the PARAMETERS spreadsheet.

Synopsis: icstat_num_attributes()

Argument: None

Example:

```
iNumAttrCols = icstat_num_attributes()
PRINT iNumAttrCols
```

icstat_num_columns Returns the number of columns in the spreadsheet. For the PARAMETERS spreadsheet, that includes the attribute and deactivated columns.

Synopsis: icstat_num_columns(<Spreadsheet-name>)

Argument:

Spreadsheet Name:	One of the Spreadsheet Names
Spreadsheet Names:	PARAMETERS, ANALYSIS, STATSUMM, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS, PARAMETER EQUATIONS, PARAMETRIC, NON PARAMETRIC

Example:

```
iNumCols = icstat_num_columns("PARAMETERS")
PRINT iNumCols
```

icstat_num_deactivated Returns the number of deactivated rows or columns in the PARAMETERS spreadsheet.

Synopsis: icstat_num_deactivated(<mode>)

Argument:

Mode: “ROW” or “COLUMN”

Example:

```
iNumDeactRows = icstat_num_deactivated("ROW")
PRINT iNumDeactRows
```

icstat_num_filtered Returns the number of filtered rows in the PARAMETERS spreadsheet.

Synopsis: icstat_num_filtered(<mode>)

Argument: None

Example:

```
iNumFilteredRows = icstat_num_filtered()
PRINT iNumFilteredRows
```

icstat_num_rows Returns the number of rows in the spreadsheet, excluding the Label row (which is usually R1). For the PARAMETERS spreadsheet, it includes the filtered and deactivated rows.

Synopsis: icstat_num_rows(<Spreadsheet -name>)

Argument:

Spreadsheet Name: One of the Spreadsheet Names

Spreadsheet Names: PARAMETERS, ANALYSIS, STATSUMM, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS, PARAMETER EQUATIONS, PARAMETRIC, NON PARAMETRIC

Example:

```
iNumRows = icstat_num_rows("PARAMETERS")
PRINT iNumRows
```

icstat_open Opens the Statistical Analysis window.

Synopsis: icstat_open()

Argument: None

Example:

```
retVal = icstat_open()
return
```

icstat_open_sdf_file Opens the SDF file.

Synopsis: icstat_open_sdf_file(<Filename>)

Arguments:

Filename: name of the SDF file to open.

Example:

```
retVal = icstat_open_sdf_file
        ("/tmp/examples/icstat/bsim3.sdf")
return
```

icstat_parameter_2_attribute Changes the Parameters column to an Attribute column in the PARAMETERS spreadsheet.

Synopsis: icstat_parameter_2_attribute (<Number>)

Argument: parameters column number to be changed to attribute type

Example:

```
retVal = icstat_parameter_2_attribute(4)
return
```

icstat_parametric_models Emulates the Parametric Models command on the Analysis menu. This function either performs the Monte Carlo, corner or boundary modeling analysis. The results are displayed in the PARAMETRIC spreadsheet.

Synopsis: icstat_parametric_models(<Number Models/Sigma>, <Type>)

Arguments:

Models/Sigma: If Monte Carlo analysis, the value represents the number of Models. If CORNER or BOUNDARY, the value is the +/-sigma.

Type: One of MONTE CARLO, CORNER or BOUNDARY

Example:

```
retVal = icstat_parametric_models(200, "MONTE CARLO")
return
```

icstat_plot_graph Emulates the Plot Graph command on the Graph menu. For the HISTOGRAM or CDF, multiple graphs can be plotted with a single call. For the scatter plot, only 1 graph can be plotted. The scatter plot requires the column numbers of 2 parameters that are to be plotted.

Synopsis: icstat_plot_graph

Arguments:

Input:	Array of column numbers to plot
Spreadsheet Name:	One of the Spreadsheet Names
Plot Type:	HISTOGRAM, CDF or SCATTER
Spreadsheet Names:	PARAMETERS, PARAMETRIC

Example:

```
complex colArr[2]
colArr[0] = 7
colArr[1] = 9
retVal = icstat_plot_graph(colArr, "PARAMETERS",
                           "SCATTER")
retVal = icstat_plot_graph(colArr, "PARAMETERS",
                          "HISTOGRAM")
retVal = icstat_plot_graph(colArr, "PARAMETERS", "CDF")
return
```

icstat_save_sdf_file Saves the data in the PARAMETERS, CORRELATION, FACTOR LOADINGS, PARAMETER VARIANCE, FACTOR EQUATIONS and PARAMETER EQUATIONS analysis spreadsheets to the named SDF file.

Synopsis:	icstat_save_sdf_file(<Filename>, <Options>)

Arguments:

Filename:	Name of the SDF file to save the data.
Options:	comma separated value TRUE|FALSE for the spreadsheets. For example: TRUE, TRUE, FALSE, FALSE, FALSE, FALSE

Example:

```
retVal = icstat_open()
sFileName = "/tmp/examples/icstat/bsim3.sdf"
retVal = icstat_open_sdf_file(sFileName)
retVal = icstat_save_sdf_file(sFileName, "TRUE, FALSE,
                              FALSE, FALSE, FALSE, FALSE")
retVal = icstat_close()
return
```

icstat_set_cell Sets the value of the particular cell in the PARAMETERS spreadsheet. Note: To set values in a large number of cells, use icstat_set_column or icstat_set_row.

Synopsis: icstat_set_cell(<number>, <row-number>, <column-number>)

Arguments:

Input: Value to set

Row Number: Integer

Column Number: Integer

Example:

```
rVal = 0.6
dummy = icstat_set_cell(rVal, 8, 8)
return
```

icstat_set_column Updates the real values in the particular column of the PARAMETERS spreadsheet with new values. The first row (R1), which is usually the label row, is not updated.

Synopsis: icstat_set_column(<Input-array>, <Column number>, <Mode>)

Arguments:

Input: Array containing the values to be set

Column Number: Integer

Mode: Mode for updating the spreadsheet column
“INSERT” inserts a new column
“OVERWRITE” overwrites the existing values

Example:

```
arrSize = icstat_num_rows("PARAMETERS")
          complex colArr[arrSize]
retArr = icstat_get_column(colArr, 9, "PARAMETERS")
dummy = icstat_set_column(retArr, 8, "OVERWRITE")
return
```

icstat_set_param_column_labels Updates the PARAMETERS spreadsheet column labels with parameter names from the Parameters table.

Synopsis: icstat_set_param_column_labels(<Path>, <From Parameter Table>)

Arguments:

Path: The name of the model or DUT from which you want to get parameter names. Specify <“model_name”> to get parameters from the Model Parameters table; specify <“model_name/DUT_name”> to get parameters from the DUT Parameters table.
(To specify the current DUT, “.” is sufficient.)

From: Specify 1 of the following parameter tables from which to get the data: “MODEL PARAMETERS”, “DUT PARAMETERS“. If left blank, “MODEL PARAMETERS” is used.

Example:

```
retVal = icstat_set_param_column_labels("/CGaas1", "MODEL
                                        PARAMETERS")
return
```

icstat_set_row Updates the real values in the specified row of the PARAMETERS spreadsheet with new values. The cells in the attribute columns (the first several columns), which typically contain text, are not updated. To update the cells in the attribute columns, use the icstat_set_text_cell function.

Synopsis: icstat_set_row(<Input-array>, <Number>, <Mode>)

Arguments:

Input:	Array containing the values to be set
Row Number:	Integer
Mode:	Mode for updating the spreadsheet row “INSERT” inserts a new row “OVERWRITE” overwrites the existing values

Example:

```
iNumAttribs = icstat_num_attributes()
iNumCols = icstat_num_columns("PARAMETERS")
iNumCells = iNumCols - iNumAttribs
          complex rowArr[iNumCells]
retArr = icstat_get_row(rowArr, 4, "PARAMETERS")
PRINT retArr
! set the 5th row
dummy = icstat_set_row(retArr, 4, "INSERT")
return
```

icstat_set_text_cell Sets the particular cell in the PARAMETERS spreadsheet with the text in the PARAMETERS spreadsheet.

Synopsis:	icstat_set_text_cell(<Row-Number>, <Column-Number>, <Text>)

Arguments:

Row Number:	Integer
Column Number:	Integer
Text:	Value to be set in the cell

Example:

```
sString = "Hi, I am a string"
retVal = icstat_set_text_cell(2, 1, sString)
retVal = icstat_get_text_cell(2, 2, "PARAMETERS",
                              "CELLVAL")
PRINT CELLVAL
return
```

icstat_stat_summary Emulates the Statistical Summary command on the Analysis menu. This function generates the statistical summary from the data in the PARAMETERS spreadsheet. Displays the results in the STATSUMM spreadsheet.

Synopsis: icstat_stat_summary()

Argument: None

Example:

```
retVal = icstat_stat_summary()
return
```

icstat_to_partable Updates the Parameters table with the corresponding parameter value from the spreadsheet. If a particular spreadsheet parameter is not found in the Parameters table or the Parameters table parameter is not found in the spreadsheet, then the value is not updated.

Synopsis: icstat_to_partable(<Row_Number>, <Path>, <From Spreadsheet Name>, <To Parameter Table>)

Arguments:

Row Number:	Row number to get the data from
Path:	The name of the model or DUT you want to update. Specify <“model_name”> to update the Model Parameters table; specify <“model_name/DUT_name”> to update the DUT Parameters table. (To specify the current DUT, “.” is sufficient.)
From:	Specify 1 of the following parameter tables from which to get the data: PARAMETERS, ANALYSIS, PARAMETRIC, NON PARAMETRIC

To:	Specify 1 of the following parameter tables to update: “MODEL PARAMETERS”, “DUT PARAMETERS”

Example:

```
retVal = icstat_to_partable(4, "/CGaas1", "PARAMETERS",
                            "MODEL PARAMETERS")
return
```

icstat_write_to_status_window Writes the input message to the Statistical Analysis Status window.

Synopsis:	icstat_write_to_status_window (<Text>)

Arguments:

Message Text:	Text to write to the Statistical Analysis Status window.

Example:

```
sString = "Setting row number 1"
retVal = icstat_write_to_status_window(sString)
return
```

integral0 Returns an integral of the given Y data set against the X data set using a simple trapezoid algorithm. The Y data set should not cross the zero point. If the Y data set has multiple curves, use *integral3*. Defined in *userc.c*.

Input Arguments:

Data Sets:	X Data, Y Data
Output:	Single real
Automatic Invocation:	On Data Set Input Change

integral3 Returns an integral of the given Y data set against the X data set using a simple trapezoid algorithm. Each curve is reported separately in the Output array. A zero cross is allowed by interpolation. Defined in *userc.c*.

Input Arguments:	
Data Sets:	X Data, Y Data
Output:	Real array
Automatic Invocation:	On Data Set Input Change

JUNCAP Philips JUNCAP (Junction Capacitance) Model. Calculates the currents and capacitances from voltages.

Input Arguments:	
Data Sets:	Anode V, Cathode V
Strings/Pars/Vars:	Output (I / IB / IS / IG / C / CB / CS / CG / Q / QB / QS / QG)
Output:	Array of complex, size determined by inputs
Extracts:	N/A

JUNCAP_TR Allows the reference temperature of the model TR in the JUNCAP model to be modified.

K707_init Keithley 707 Switch Matrix function. Initialize the 707 matrix. Do not use this function with the 708a matrix.

Syntax

```
int ret = K707_init(MatrixGPIBAddr)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

Examples:

ret = K707_init(6) // Init matrix at address 6

K708a_init Keithley 708a Switch Matrix function. Initialize the 708a matrix. Do not use this function with the 707 matrix.

Syntax

```
int ret = K708a_init(MatrixGPIBAddr)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

Examples:

ret = K708a_init(6) // Init matrix at address 6

K70X_clear_setup Keithley 707 Switch Matrix function. Clears setup (opens all relays).

Syntax

```
int ret = K70X_clear_setup(MatrixGPIBAddr, Setup)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

Setup: setup to be cleared (all crosspoints are opened) SetUp can be a memory setup or the actual relays configuration 0 <= SetUp < 100.

Examples:

ret = K70X_clear_setup(6, 0) open all relays in the actual matrix configuration

ret = K70X_clear_setup(6, 1) open all relays in the memory setup number 2

K70X_close_crosspoints Keithley 707 Switch Matrix function. Closes crosspoints in the matrix.

Syntax

```
int ret = K70X_close_crosspoints(MatrixGPIBAddr,
                                 CrosspointList)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

CrosspointList: List of the crosspoint to be close (string).

Example:

ret = K70X_close_crosspoints(6, “A1,C12”) opens the crosspoints specified in the list in the current edited setup specified by the K70X_edit_setup function.

K70X_config_trigger Keithley 707 Switch Matrix function. Configures trigger.

Syntax

```
int ret = K70X_config_trigger(MatrixGPIBAddr,
                              TriggerEdge, TriggerSource)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix.

TriggerEdge: “+” or “-”

TriggerSource: Possible configurations: “TALK” “GET” “X” “EXT” “MAN”

Example:

ret = K70X_config_trigger(6, “+”, “EXT”) sets the switch matrix to execute when receiving a positive edge from an external trigger. See 70X manual for a more detailed explanation about triggering the matrix.

K70X_connect_sequence Keithley 707 Switch Matrix function. Sets the connection rule and the row connection sequence.

Syntax

```
int ret = K70X_connect_sequence(MatrixGPIBAddr,
                                ConnectionRule,
                                RowConnectionSequence)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

ConnectionRule: Break before Make “BM” or “MB”

RowConnectionSequence: byte row enable. Ex.: “11110011”

Example:

ret = K70X_connect_sequence(6,“BM”,“11110011”)

K70X_copy_setup Keithley 707 Switch Matrix function. Copy setup into a new memory or actual location.

Syntax

```
int ret = K70X_copy_setup(MatrixGPIBAddr, Source,
                          Destination)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

Source: Setup to be copied from.

Destination: Setup to be copied to.

Example:

ret = K70X_copy_setup(6, 3, 0) copies the memory setup 3 into the setup 0 (actual matrix configuration). In other words, it executes setup 3.

K70X_debug Keithley 707 Switch Matrix function. Sets debug flag on or off. When the debug mode is on, the functions will print debug information in the Warning/Error window

Syntax

```
int ret = K70X_debug(Debugflag)
```

Where

DebugFlag: 1/0 (Default is 0)

K70X_delete_setup Keithley 707 Switch Matrix function. Deletes setup from memory.

Syntax

```
int ret = K70X_delete_setup(MatrixGPIBAddr, MemSetup)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

MemSetup: memory setup to be deleted. 1< MemSetup < 100

Example:

ret = K70X_delete_setup(6, 3) deletes memory setup number 3.

K70X_edit_setup Keithley 707 Switch Matrix function. Sets the setup number to be edited with the following close and open commands. Note that setup number 0 represents the matrix actual configuration while Setup 1 to 100 represents memory setups.

Syntax

```
int ret = K70X_edit_setup(MatrixGPIBAddr, SetUp)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

SetUp: Number of the setup to edit with the next close and open commands.

Example:

ret = K70X_edit_setup(6, 1) sets to edit the memory setup number 1.

K70X_init_interface Keithley 708a and 707 Switch Matrix function. Initialize the interface card or lan. It must be executed prior to any other Keithley transform.

Syntax

```
int ret = K70X_init_interface(InterfaceName)
```

Where

InterfaceName is the hardware interface.

Examples:

ret = K70X_init_interface(“hpib”)

ret = K70X_init_interface(“gpib0”)

ret = K70X_init_interface(“lan[xx.xx.xx.xx]:hpib”)

K70X_open_crosspoints Keithley 707 Switch Matrix function. Opens crosspoints in the matrix.

Syntax

```
int ret = K70X_open_crosspoints(MatrixGPIBAddr,
                                CrosspointList)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix

CrosspointList: List of the crosspoint to be open (string).

Example:

ret = K70X_open_crosspoints(6, “A1,C12,D1”) opens the crosspoints specified in the list in the current edited setup specified by the K70X_edit_setup function.

K70X_trigger_disable Keithley 707 Switch Matrix function. Disables trigger.

Syntax

```
int ret = K70X_trigger_disable(MatrixGPIBAddr)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix.

Example:

ret = K70X_trigger_disable(6)

K70X_trigger_enable Keithley 707 Switch Matrix function. Enables trigger.

Syntax

```
int ret = K70X_trigger_enable(MatrixGPIBAddr)
```

Where

MatrixGPIBAddr is the GPIB address of the matrix.

Example:

ret = K70X_trigger_enable(6)

linfit Fits a line to a specified curve (step) in a data set (X versus Y). Returns a 3 point data set that defines slope, intercept and regression coefficient. The index of steps starts at 0. If the OVERRIDE_LIMITS variable is TRUE, the limits can be specified manually with the X_LOW and X_HIGH variables, which can be set from the Plot menu. (Use the *fit_line* function to enable plotting of the data set, rather than the slope and intercept.)

Input Arguments:

Data Sets:	X Data, Y Data
Reals or Integers:	Step Number (0 is first)
Output:	Array of 2 points: slope then intercept
Automatic Invocation:	None

Example PEL Statement:

```
fit_data = linfit(vc,ic.m,0)
```

LINKarray Returns an array result from an IC-CAP Macro algorithm to an IPC Link program during linked mode execution. This function is used internally by IPC Link programs and should never be called directly when using IC-CAP interactively.

Input Arguments:

Data Sets:	Array Result
Reals or Integers:	Array Size, Result Data Index
Output:	None
Automatic Invocation:	None

LINKchar Returns a single character result from an IC-CAP Macro algorithm to an IPC Link program during linked mode execution. This function is used internally by IPC Link programs and should never be called directly when using IC-CAP interactively.

Input Arguments:

Reals or Integers:	Result Data Index
Strings/Pars/Vars:	Character Result
Output:	None
Automatic Invocation:	None

LINKint Returns an integer result from an IC-CAP Macro algorithm to an IPC Link program during linked mode execution. This function is used internally by IPC Link programs and should never be called directly when using IC-CAP interactively.

Input Arguments:

Reals or Integers:	Integer Result, Result Data Index
Output:	None
Automatic Invocation:	None

LINKpin Used in an IC-CAP Macro to determine the matrix connections of the device under test. LINKpin returns the matrix pin number that corresponds to a specified terminal index on the device. This function only returns valid data when an IPC Link program has provided a pin mapping.

Input Arguments:

Reals or Integers:	Terminal Index
Output:	Matrix pin number corresponding to the specified device terminal index
Automatic Invocation:	None

Example PEL Statement:

```
pin_num = LINKpin(1)
```

LINKreal Returns a floating point result from an IC-CAP Macro algorithm to an IPC Link program during linked mode execution. This function is used internally by IPC Link programs and should never be called directly when using IC-CAP interactively.

Input Arguments:

Reals or Integers:	Real Result, Result Data Index
Output:	None

Automatic Invocation: None

LINKstr Used to return a character string result from an IC-CAP Macro algorithm to an IPC Link program during linked mode execution. This function is used internally by IPC Link programs and should never be called directly when using IC-CAP interactively.

Input Arguments:
  Result Data Index: String Result
Output: None
Automatic Invocation: None

log Natural logarithm.

Input Arguments:
  Data Sets: Input 1
Output: Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation: On Data Set Input Change

log10 Base 10 logarithm.

Input Arguments:
  Data Sets: Input 1
Output: Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation: On Data Set Input Change

lookup_par Enables you to access the value of a parameter referenced by a string. A second argument may be specified that is a variable to receive any error string normally going to a red error box.

Example — looking up value for model parameter:

```
x=lookup_par("/npn.IS")
```

Example — looking up value for DUT parameter:

```
x=lookup_par(“/NPN/dc.rgate”)
```

Example — checking existence of parameter:

```
x=lookup_par("nonexistantparam",errstr)
if errstr<>"" then print errstr
```

lookup_var Enables you to access the value of a variable referenced by a string. A second argument may be specified that is a variable to receive any error string normally going to a red error box.

Example — looking up value for model variable:

```
x=lookup_var("/npn/SIMULATOR")
```

Example — looking up value for DUT variable:

```
x=lookup_var(“/NPN/dc/TEMP”)
```

Example — looking up value for Setup variable:

```
x=lookup_var(“/NPN/dc/fgummel/Vdmax”)
```

Example — checking existence of variable:

```
x=lookup_var("nonexistantvar",errstr)
if errstr<>"" then print errstr
```

mean Calculates the arithmetic mean of a data set. Returns a single value. Adequate for a real or complex data set, but if a data set of matrices is received, only the 1,1 data is considered. A data set specification like *S.21* is adequate, since this is a data set of complex numbers.

Input Arguments:

Data Sets:	Input 1
Output:	Single real or complex number
Automatic Invocation:	On Data Set Input Change

mem_diag This function is reserved for factory use; it is used in memory utilization regression tests, as part of the IC-CAP quality assurance process.

Output:	A 12-point data set containing memory utilization statistics
Automatic Invocation:	None

MEXTRAM_stoc Mextram model version: 504

This function calculates capacitance data from S-parameter data, allowing base-collector and base-emitter capacitance to be calculated from network analyzer measurements. The output of this function can be used in place of actual capacitance data to extract capacitance-related parameters.

Input Arguments:	
FREQ data	Frequency
S data	s-parameter data (de-embedded)
Node (C/E/S)	Code to indicate type of extraction: E base-emitter capacitance C base-collector capacitance S substrate-collector capacitance
Output:	Capacitance versus frequency data
Extracts:	Nothing

MM9 Calculates Id, Is or Ib from voltages.

Input Arguments:	
Data Sets:	Drain V, Gate V, Bulk V, Source V
Strings/Pars/Vars:	Output (D / S / B)
Output:	Drain I / Source I / Bulk I - array of complex, size determined by inputs
Extracts:	None

MM9_COPY Copies an input array to a measured or simulated output dataset.

Input Arguments:

Data Sets:	Copy from (Dataset Name)
Strings/Pars/Vars:	Copy to (Dataset Name) M or S
Output:	None

MM9_DATA Enables printing of the data measured for quick extraction.

Input Arguments: “” or “<filename>”

Example:

```
x = MM9_DATA(“”)
```

or

```
x = MM9_DATA(“mm9_print“)
```

If no argument is supplied, the data will be printed to the Status window; if a filename is supplied, the data will be appended to that file.

MM9_GEOMPAR Updates the simulated values of the miniset parameters in the setups *extract/par_vs_L*, *extract/par_vs_W* and *extract/par_vs_R* in the MOS Model 9.

MM9_GEOMSCAL Determines a first guess for the maxiset parameters of a MOS Model 9 by regression.

MM9_KEEP Accepts an input array and copies it directly to the transform output.

Input Arguments:

Data Sets:	Keep array (Dataset name)
Output:	Array of complex, size determined by inputs

MM9_LIN_EXT Extracts the linear region parameters for the MOS Model 9.

Input Arguments:	None
Extracts:	VTO, KO, K, VSBX, BET, THE1, THE2

MM9_SAT_EXT Extracts the saturation region parameters for the MOS Model 9.

Input Arguments:	None
Extracts:	THE3, GAM1, ETADS, ALP, VP

MM9_SAVE_SPARS Saves the MOS Model 9 parameters of a single device (miniset) to a file.

MM9_SETUP Allows you to specify the setups for the MOS Model 9 parameter extraction.

MM9_STH_EXT Extracts the subthreshold region parameters for the MOS Model 9.

Input Arguments:	None
Extracts:	GAMOO, MO, ZET1, VSBT

MM9_TEMPPAR Updates the simulated values of the miniset parameters in the setups *extract/par_vs_T* in the MOS Model 9.

MM9_TEMPSCAL Determines a first guess for the maxiset temperature parameters of a MOS Model 9 by regression.

MM9_WEAVAL_EXT Extracts the weak avalanche region (substrate current) parameters for the MOS Model 9.

Input Arguments:	None
Extracts:	A1, A2, A3

MOS_process_pars Allows you to specify initial values for the MOS process related parameters LD, RS, RSH, TOX, WD, and XJ. The drain resistance RD is set equal to the specified value of RS.

Input Arguments:	
Data Sets:	Lateral Diffusion, Source Resistance, Sheet Resistance, Oxide Thickness, Width Reduction, Junction Depth
Output:	None
Extracts:	(not applicable)
Automatic Invocation:	By Extract menu function

MOSCV_total_cap Extracts the total PN junction capacitance parameters from the bottom and sidewall. Requires C-V measurement on 2 different geometries. The first measurement should be on a device in which the bottom capacitance dominates. The second measurement should be on a device in which the sidewall capacitance dominates.

Input Arguments:	
Data Sets:	Cap 1, Cap 2, Junction V
Reals or Integers:	Cap 1 Area, Cap 1 Perim, Cap 2 Area, Cap 2 Perim
Output:	None
Extracts:	CJ, MJ, CJSW, MJSW, PB
Automatic Invocation:	By Extract menu function

MOSCVmodCBD Calculates the Bulk-Drain junction capacitance according to the UCB MOS model.

Input Arguments:

Data Sets:	Junction V
Output:	Array of complex; size determined by inputs
Automatic Invocation:	None

MOSCVmodCBS Calculates the Bulk-Source junction capacitance according to the UCB MOS model.

Input Arguments:

Data Sets:	Junction V
Output:	Array of complex; size determined by inputs
Automatic Invocation:	None

MOSDC_lev2_lin_large Standard extraction for the UCB MOS model. Extracts classical Level 2 parameters, using I_d versus V_g data from a large device. Initializes the parameter NFS for later optimization.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	VTO, NSUB, UO, UEXP, VMAX
Automatic Invocation:	By Extract menu function

MOSDC_lev2_lin_narrow Standard extraction for the UCB MOS model. Extracts Level 2 width parameters, using I_d versus V_g data from a narrow device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None

Extracts: WD, DELTA

Automatic Invocation: By Extract menu function

MOSDC_lev2_lin_short Standard extraction for the UCB MOS model. Extracts Level 2 length effect parameters, using I_d versus V_g data from a short-channel device.

Input Arguments:

Data Sets: Gate V, Bulk V, Drain V, Drain I

Output: None

Extracts: XJ, LD

Automatic Invocation: By Extract menu function

MOSDC_lev2_sat_short Standard extraction for the UCB MOS model. Extracts Level 2 saturation parameters, using Id versus Vd data from a short-channel device.

Input Arguments:

Data Sets: Gate V, Bulk V, Drain V, Drain I

Output: None

Extracts: VMAX, NEFF

Automatic Invocation: By Extract menu function

MOSDC_lev3_lin_large Standard extraction for the UCB MOS Level 3 model. Extracts classical Level 3 parameters, using I_d versus V_g data from a large device. Initializes the parameter NFS for later optimization.

Input Arguments:

Data Sets: Gate V, Bulk V, Drain V, Drain I

Output: None

Extracts: VTO, NSUB, UO, THETA, VMAX

Automatic Invocation: By Extract menu function

MOSDC_lev3_lin_narrow Standard extraction for the UCB MOS Level 3 model. Extracts Level 3 width parameters, using I_d versus V_g data from a narrow device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	WD, DELTA
Automatic Invocation:	By Extract menu function

MOSDC_lev3_lin_short Standard extraction for the UCB MOS Level 3 model. Extracts Level 3 length effect parameters, using I_d versus V_g data from a short device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	RS, RD, LD, XJ
Automatic Invocation:	By Extract menu function

MOSDC_lev3_sat_short Standard extraction for the UCB MOS Level 3 model. Extracts Level 3 saturation parameters, using I_d versus V_d data from a short device.

Input Arguments:

Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	VMAX, KAPPA, ETA
Automatic Invocation:	By Extract menu function

MOSDC_lev6_lin_large Standard extraction for the HSPICE MOS Level 6 model. Extracts classical Level 6 parameters, using I_d versus V_g data from a large device. Initializes the parameter NFS for later optimization.

Input Arguments:	
Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	PHI, VT, LGAMMA, GAMMA, VBO, LAMBDA, UB, NFS
Automatic Invocation:	By Extract menu function

MOSDC_lev6_lin_narrow Standard extraction for the HSPICE MOS Level 6 model. Extracts Level 6 width parameters, using I_d versus V_g data from a narrow device.

Input Arguments:	
Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	NWM, WDEL, DELTA
Automatic Invocation:	By Extract menu function

MOSDC_lev6_lin_short Standard extraction for the HSPICE MOS Level 6 model. Extracts Level 6 length effect parameters, using I_d versus V_g data from a short device.

Input Arguments:	
Data Sets:	Gate V, Bulk V, Drain V, Drain I
Output:	None
Extracts:	SCM, XJ, LDEL
Automatic Invocation:	By Extract menu function

MOSmodel Simple, level 1 UCB MOS model. Calculates Id from voltages.

Input Arguments:	
Data Sets:	Drain V, Gate V, Bulk V, Source V
Output:	Array of complex; size determined by inputs
Automatic Invocation:	None

MOSmodel2 Complete UCB MOS model, containing levels 1, 2, and 3. Calculates I_d from voltages.

Input Arguments:	
Data Sets:	Drain V, Gate V, Bulk V, Source V
Output:	Array of complex; size determined by inputs
Automatic Invocation:	None

MXT_cbc Mextram model version: 504

This function calculates the total base-collector depletion capacitance Cbc vs. bias given vbc.

Inputs:	
VBC:	base-collector voltage
Output:	calculated total base-collector capacitance.

See Philips Report NL-UR 2001/801, section 2.5.2 for more details.

MXT_cbe Mextram model version: 504

This function calculates the total base-emitter depletion capacitance Cbe vs. bias given vbe.

Inputs:

VBE:	base-emitter voltage
Output:	calculated total base-emitter depletion capacitance.

See Philips Report NL-UR 2001/801, section 2.5.1 for more details.

MXT_cj0 Mextram model version: 504

This function extracts the zero-bias junction capacitance, Cje0, Cjc0 or Cjs0 depending on which Output mode is selected: E/C/S. The total bias range needs to include V = 0 V, but it is not necessary that one of the Vj value is indeed zero.

See Philips Report NL-UR 2001/801, sections 2.5.1-2.5.3 for more details.

MXT_csc Mextram model version: 504

This function calculates the total substrate-collector depletion capacitance Csc vs. bias given vsc.

Inputs:

VSC:	substrate-collector voltage
Output:	calculated total substrate-collector depletion capacitance.

See Philips Report NL-UR 2001/801, section 2.5.3 for more details.

MXT_forward_hfe Mextram model version: 504

This function calculates hfe given veb,vcb and ic.m. When the MODEL variable MXT_AUTO_RANGE is set to the value 1.0 the transform will use the measured collector current to determine the upper limit for extracting the parameters: BF, IBF and MLF. This limit is determined by the onset of

high-injection. The function is used in the dc_gummel/Forward setup to extract the non ideal base current parameters IBF, MLF and the forward current gain BF.

Inputs:	
VEB:	emitter-base voltage.
VCB:	collector-base voltage (it should be constant)
IC:	measured collector current
Output:	forward current gain Ic//Ib

See Philips Report NL-UR 2001/801, section 2.5.8 for more details.

MXT_forward_ic Mextram model version: 504

This function calculates ic given veb and vcb. When the MODEL variable MXT_AUTO_RANGE is set to the value 1.0 this transform will also require ic.m as an input. The transform uses the measured collector current to determine the upper limit for extracting the parameter: IS. This limit is set by the onset of high-injection. The function is used to extract IS in the setup dc_gummel/Forward.

Inputs:	
VEB:	emitter-base voltage.
VCB:	collector-base voltage (this should be constant in a forward gummel plot)
IC:	measured collector current (used for auto-ranging)
Output:	calculated ideal forward collector current (DO NOT include series resistances, high injection, quasi-sat etc.)

See Philips Report NL-UR 2001/801, section 2.5.7 for more details.

MXT_forward_vbe Mextram model version: 504

This function calculates vbe given vcb, ic.m and ib.m. When the MODEL variable MXT_AUTO_RANGE is set to the value 1.0, the transform will also require veb (ve-vb) as an input. The transform is used to optimize RE in the setup dc_gummel/Forward.

Inputs:	
IC:	measured collector current.
IB:	measured base current.
VEB:	external measured Veb (used for auto-ranging only)
Output:	external voltage Vbe.

See Philips Report NL-UR 2001/801, section 2.5.9 for more details.

MXT_ft Mextram model version: 504

This function calculates the cut-off frequency fT as a function of Ic, Vbe and Vce. The function is used to extract the transit time parameters as well as several other high current parameters.

Inputs:	
IC:	measured collector current.
VBE:	base-emitter voltage.
VCE:	collector-emitter voltage.
Output:	calculated fT.

See Philips Report NL-UR 2001/801, section 2.6 for more details.

MXT_hard_sat_isub Mextram model version: 504

This function calculates the substrate current in hard saturation. It is used in the dedicated setup dc_paras/Rc_active to extract the parameter RCC.

Inputs:

VBC:	base-collector voltage.
IC:	measured collector current.
IB:	measured base current.
Output:	calculated substrate current in hard saturation.

See Philips Report NL-UR 2001/801, section 2.5.10 for more details.

MXT_ic_vce Mextram model version: 504

This function calculates the collector current or the base emitter voltage (depending on the selected Output) as function of the voltage difference Vce and the base current Ib. Ic is used to correct for series resistances. Vbe and Is are used for setting initial values in the calculation and for auto-ranging.

NOTE Auto-ranging is always ON for this function, regardless of the value of the variable MXT_AUTO_RANGE.

The function is used to extract the model variable RTH (thermal resistance) and several other parameters in combination with the MXT_ft transform. RTH along with Ic and Vce are used to calculate a new simulation temperature. To remove RTH's influence on the simulation temperature, set RTH to zero.

Inputs:	
VCE:	collector-emitter voltage.
IB:	measured base current.
IC:	measured collector current.
VBE:	base-emitter voltage.
ISUB:	measured substrate current.
Output [i/v]:	choice of collector current (i) or base-emitter voltage (v)
Avalanche [y/n]:	Yes/No flag.
Output:	calculated collector current or base-emitter voltage.

See Philips Report NL-UR 2001/801, section 2.6 for more details.

MXT_I0 Mextram model version: 504

This function extracts either IE0, IC0, or IB0 depending on which Output mode is selected: E/C/B. The function requires a terminal current as input. This transform uses the array of current data Idata and takes the first value at index 0. The I0 value can be used in the forward-Early and reverse-Early measurements to get a first estimate of the current offset. The subsequent optimizations, which require either IE0, IB0 or IC0, provide more robust results. Sometimes the optimizer will have trouble converging to a proper solution if these currents are too far from their final values.

Inputs:	
Idata:	dataset with current data
Choice of outputs:	E/C/B
Output:	Sets the value of the model variables IE0,IC0 or IB0

See Philips Report NL-UR 2001/801, section 2.5.4-2.5.6 for more details.

MXT_jun_cap Mextram model version: 504

This function calculates Cbe, Cbc, or Csc vs junction voltage given vbe, vbc, or vsc. This function combines the functionalities of the 3 functions: MXT_cbe, MXT_cbc, MXT_csc.

Input Arguments:

VJUN	junction voltage: vbe, vbc, or vsc
OUTPUT: E/C/S	Code to indicate which junction to calculate E (default) Cbe: requires vbe as VJUN input C Cbc: requires vbc as VJUN input S Csc: requires vsc as VJUN input
Output:	junction capacitance vs junction voltage data

MXT_reverse_currents Mextram model version: 504

Selecting Output=B calculates ib given vbc, vbe and ie. When the MODEL variable *MXT_AUTO_RANGE* is set to the value 1.0, the transform will use the measured emitter current to determine the lower limit for extracting the parameters: XEXT and IKS. This limit is set by the onset of high-injection.

Selecting Output=S calculates is given vbc, vbe and ie. When the MODEL variable *MXT_AUTO_RANGE* is set to the value 1.0, the transform will use the measured emitter current to determine the lower limit for extracting the parameters: XEXT and IKS. This limit is set by the onset of high-injection.

Selecting Output=E calculates ie given vbc, vbe and ie. When the MODEL variable *MXT_AUTO_RANGE* is set to the value 1.0, the transform will use the measured emitter current to

determine the lower limit for extracting the parameters: XEXT and IKS. This limit is set by the onset of high-injection.

Inputs:

VBC:	base-collector voltage.
VBE:	base-emitter voltage.
IE:	measured emitter current (for auto-ranging only)
Output [E/B/S]:	select: E for emitter current B for base current S for substrate current
Output:	calculated reverse current (emitter/base or substrate).

See Philips Report NL-UR 2001/801, section 2.6.7 for more details.

MXT_reverse_hfc Mextram model version: 504

This function calculates HFC (ie/ib) given veb, vcb and ie.m. When the MODEL variable *MXT_AUTO_RANGE* is set to the value 1.0, the transform uses the measured emitter current to determine the upper limit for extracting the parameter BR, IBR, VLR. This limit is set by the onset of high-injection. This transform has an additional input: substrate (y/n). This is used to calculate the reverse beta with or without the addition of the substrate current.

Inputs:

VCB:	collector-base voltage.
VEB:	emitter-base voltage.
IE:	measured emitter current (for auto-ranging only)
I Substrate [Y/N]:	yes or no field.

Output:	calculated reverse current gain Hfc= Ie//Ib = Ie/(Iex+Ib3+Isub)

See Philips Report NL-UR 2001/801, section 2.5.12 for more details.

MXT_reverse_hfc_sub Mextram model version: 504

This function calculates the substrate to emitter current gain: HFCsub (-ie/is) given veb and vcb. The function is used in the setup dc_gummel/Reverse to extract the parameter ISS. When the MODEL variable *MXT_AUTO_RANGE* is set to the value 1.0, the transform will require 2 additional inputs: emitter and substrate currents (ie) & (is). The transform uses the measured emitter & substrate currents to determine the upper limit for extracting the parameter ISS. This limit is set by the onset of high-injection in both the emitter and substrate currents.

Inputs:

VEB:	emitter-base voltage.
VCB:	collector-base voltage.
IE:	measured emitter current
IS:	measured substrate current.
Output:	calculated substrate to emitter current gain Ie//Isub

See Philips Report NL-UR 2001/801, section 2.5.11 for more details.

MXT_reverse_isub Mextram model version: 504

This function calculates the substrate current for low reverse conditions. It can be used to extract the parameter ISS, however Philips recommends another method (see section 2.5.11).

Inputs:

VBC:	base-collector voltage (positive as transistor reverse biased)
IS:	measured Is (used for auto-ranging only)
Output:	calculated substrate current Isub = ISS*(exp(Bbc/VT)-1) where VT is the thermal voltage.

See Philips Report NL-UR 2001/801, section 2.5.11 for more details.

MXT_show_parms Mextram model version: 504

This function prints all the Mextram parameters at the actual ambient temperature set by the variable TEMP. The functions will use these parameters in their calculations.

See Philips Report NL-UR 2001/801, section 5.1.1 for more details.

mxt_smooth This function is obsolete.

This function performs a smoothing function on the data.

Input Arguments:

Y Data	unitless
Smooth Points	number of points on either side of data point to be use for smoothing. 0 = disable
Smooth Iter	number of iterations that smoothing algorithm is performed on data. 0 = disable
Output:	Smoothed data.

MXT_veaf_ib Mextram model version: 504

This function calculates the base current in a forward early measurement. It is used in the setup dc_early_avl/Fwd_early to extract the avalanche parameters VAVL and WAVL.

Inputs:

VCB:	collector-base voltage.
IC:	measured collector current.

the function uses the model variable IB0

Output: calculated base current

See Philips Report NL-UR 2001/801, section 2.5.4 for more details.

MXT_veaf_ic Mextram model version: 504

This function calculates forward current ic given vcb, veb and the model variable *IC0*. When the MODEL variable *MXT_AUTO_RANGE* is set to the value 1.0, the transform will require one additional input: base current ib. The transform uses the measured base current to determine the onset of weak avalanche breakdown. This sets the upper limit of the optimization, opt_Veaf.

Inputs:

VCB:	collector-base voltage.
VEB:	emitter-base voltage (this should be constant).
IB:	measured base current, used for autorange only.

the function uses the model variable IC0

Output: calculated collector current Ic (transistor forward bias)

See Philips Report NL-UR 2001/801, section 2.5.6 for more details.

MXT_vear_ie Mextram model version: 504

This function calculates ie when the base emitter junction is reversed biased, and the base collector junction is forward biased. Vcb is assumed to be constant. The function is used in the setup dc_early_avl/Rev_early to extract the parameter VER.

Inputs:

VEB:	emitter-base voltage.
VCB:	collector-base voltage (it should be constant and > 0).

the function uses the model variable IE0.

Output:	emitter current Ie (transistor reverse biased)

See Philips Report NL-UR 2001/801, section 2.5.5 for more details.

MXT_VEF Mextram model version: 504

This function calculates a starting value for the parameter VEF. The Model Parameter list is updated and the extracted value is printed in the status window. To extract VEF, run this transform first and then optimization opt_VEF in the setup dc_early_avl/Fwd_early.

Input Argument:

VCB:	collector-base voltage.
IC:	measured collector current

See Philips Report NL-UR 2001/801, section 2.5.6 for more details.

MXT_VER Mextram model version: 504

This function calculates a starting value for the parameter VER. The Model Parameter list is updated and the extracted value is printed in the status window. To extract VER, run this transform first and then optimization opt_VER in the setup dc_early_avl/Rev_early.

Input Argument:

VCB:	collector-base voltage.
IC:	measured collector current

See Philips Report NL-UR 2001/801, section 2.5.5 for more details.

mxt3t_cbc This function is obsolete.

This function calculates Cbc verses base collector junction voltage.

Input Arguments:

Vbc	Vbc Voltage (V)
Output:	Cbc

mxt3t_cbe This function is obsolete.

This function calculates Cbe verses base emitter junction voltage.

Input Arguments:

Vbe	Vbe Voltage (V)
Output:	Cbe

mxt3t_cj0 This function is obsolete.

This function extracts the zero-bias junction capacitance, Cje0, or Cjc0 depending on which Output mode is selected: E/C/S.

Input Arguments:

Junction Voltage V

Junction Capacitance C

Junction: E, C

Output: Cje or Cjc depending on Junction argument

mxt3t_ft_ic This function is obsolete.

This function calculates FT given Ic, Vbe, and Vce.

NOTE This function does not describe Ft when quasi saturation kicks in. Use mxt3t_ft_ic_new instead.

Input Arguments:

Ic	Collector Current (A)
Vbe	Base Emitter Voltage (V)
Vce	Vce Voltage (V)

Output: Ft

mxt3t_ft_ic_new This function is obsolete.

This function calculates FT given Ic, Vbe, and Vce.

NOTE This new function now includes quasi but not heavy saturation.

Input Arguments:

Ic	Collector Current (A)
Vbe	Base Emitter Voltage (V)
Vce	Vce Voltage (V)
Output:	Ft

mxt3t_fwd_early_ib This function is obsolete.

This function calculates the fwd early base current for a 3 terminal device given Vcb and Ic.

Input Arguments:

Vcb	Vcb Voltage (V)
ic	Ic current (A)
Output:	Forward Early base current.

mxt3t_fwd_early_ic This function is obsolete.

This function calculates the fwd early collector current for a 3 terminal device given Vbe and Vbc.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Output:	Forward Early collector current.

mxt3t_fwd_gummel_hfe This function is obsolete.

This function calculates forward gummel HFE for a 3 terminal device given Vbe, Vbc, and Ic. The HFE limit input limits HFE to the value entered. This is used to limit HFE in the region outside of the function's applicable range.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ic	Collector Current (A)
HFE Limit	Maximum HFE to be displayed.
Output:	Forward Gummel HFE

mxt3t_fwd_gummel_ib This function is obsolete.

This function calculates the forward gummel base current for a 3 terminal device given Vbe, Vbc, and Ic.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ic	Collector Current (A)
Output:	Forward Gummel Base current.

mxt3t_fwd_gummel_ic This function is obsolete.

This function calculates forward gummel collector current for a 3 terminal device given Vbe, Vbc.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Output:	Forward Gummel Collector current.

mxt3t_fwd_gummel_vbe This function is obsolete.

This function calculates forward gummel base-emitter voltage for a 3 terminal device given Ib and Ic.

Input Arguments:

ib	Base current (A)
Ic	Collector Current (A)
Output:	Forward Gummel Vbe.

mxt3t_i0 This function is obsolete.

This function extracts either IE0, IC0 or IB0 depending on which Output mode is selected: E/C/B. The function requires a terminal current as input. This transform was written to make the subsequent optimizations, which require either IE0, IB0 or IC0, more robust. Sometimes the optimizer would have trouble converging to a proper solution if these currents were too far from their final values.

Input Arguments:

I Data (A)	
Output: E, C, B	
Output:	IE0, IC0, IB0 depending on Output Argument

mxt3t_linear_range This function is obsolete.

This function calculates the 2nd derivative of a dataset. It enables the user to see where the data is linear. This is useful in determining the valid range of mextram functions.

Input Arguments:

Y Data	unitless
X Data	unitless (must be uniform steps)
Smooth Points	number of points on either side of data point to be use for smoothing. 0 = disable

Smooth Iter	number of iterations that smoothing algorithm is performed on data. 0 = disable
Log Data ?	Log the data before the smoothing or derivative functions are applied
Output:	2nd derivative of the Y Data.

mxt3t_output_ic This function is obsolete.

This function calculates collector current output characteristics given Vce, Ic, Ib, and Vb. It is intended to model the quasi-saturation region of the transistor.

Input Arguments:

Vce	Vce Voltage (V)
Ic	Collector Current (A)
Ib	Base Current (A)
Vb	Base Voltage (V)
Output:	Collector Current

mxt3t_output_vbe This function is obsolete.

This function calculates base-emitter voltage Vce, Ic, Ib, and Vb. It is used to estimate the thermal resistance of the device.

Input Arguments:

Vce	Vce Voltage (V)
Ic	Collector Current (A)
Ib	Base Current (A)
Vb	Base Voltage (V)
Output:	Base Emitter Voltage

mxt3t_rev_early_ie This function is obsolete.

This function calculates the reverse early emitter current for a 3 terminal device given Vbe and Vbc.

Input Arguments:	
Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Output:	Reverse Early emitter current.

mxt3t_rev_early_qb0_guess This function is obsolete.

This function calculates QBO based on the following formula:

QBO = IE0*(1-XCJE)*CJE*(dvbe/die @ vbe=0)

The function requires ie and vbe as inputs and the model parameters mex.CJE, mex.XCJE and the model variable IE0.

This transform was written for 2 reasons: (1) the optimization used to determine its final value can get lost if the initial value is way off; (2) The value of QBO is used to determine the initial values of other parameters. Therefore, the more accurate the value of QBO the more accurate these other parameters will be.

Input Arguments:	
Vbe	Vbe Voltage (V)
Ie	Emitter Current (A)
Output:	QB0

mxt3t_rev_gummel_hfc This function is obsolete.

This function calculates the reverse gummel HFC for a 3 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ie	Emitter Current (A)
Output:	Reverse Gummel HFC.

mxt3t_rev_gummel_ib This function is obsolete.

This function calculates the reverse gummel base current for a 3 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ie	Emitter Current (A)
Output:	Reverse Gummel Base current.

mxt3t_rev_gummel_ie This function is obsolete.

This function calculates the reverse gummel emitter current for a 3 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ie	Emitter Current (A)
Output:	Reverse Gummel Emitter current.

mxt4t_cbc This function is obsolete.

This function calculates Cbc verses base collector junction voltage.

Input Arguments:

Vbc	Vbc Voltage (V)
Output:	Cbc

mxt4t_cbe This function is obsolete.

This function calculates Cbe verses base emitter junction voltage.

Input Arguments:

Vbe	Vbe Voltage (V)
Output:	Cbe

mxt4t_cj0 This function is obsolete.

This function extracts the zero-bias junction capacitance, Cje0, Cjc0 or Cjs0 depending on which Output mode is selected: E/C/S.

Input Arguments:

Junction Voltage V

Junction Capacitance C

Junction: E, C, S

Output:	Cje, Cjc, or Cjs depending on Junction argument

mxt4t_csc This function is obsolete.

This function calculates Csc verses collector junction voltage.

Input Arguments:

Vsc	Vsc Voltage (V)
Output:	Csc

mxt4t_ft_ic This function is obsolete.

This function calculates FT given Ic, Vbe, and Vce.

NOTE This function does not describe Ft when quasi saturation kicks in. Use mxt4t_ft_ic_new instead.

Input Arguments:

Ic	Collector Current (A)
Vbe	Base Emitter Voltage (V)
Vce	Vce Voltage (V)
Output:	Ft

mxt4t_ft_ic_new This function is obsolete.

This function calculates FT given Ic, Vbe, and Vce.

NOTE This new function now includes quasi but not heavy saturation.

Input Arguments:

Ic	Collector Current (A)
Vbe	Base Emitter Voltage (V)
Vce	Vce Voltage (V)
Output:	Ft

mxt4t_fwd_early_ib This function is obsolete.

This function calculates the fwd early base current for a 4 terminal device given Vcb and Ic.

Input Arguments:

Vcb	Vcb Voltage (V)
ic	Ic current (A)
Output:	Forward Early base current.

mxt4t_fwd_early_ic This function is obsolete.

This function calculates the fwd early collector current for a 4 terminal device given Vbe and Vbc.

Input Arguments:

Vbe	Vbe Voltage (V
Vbc	Vbc Voltage (V)
Output:	Forward Early collector current.

mxt4t_fwd_gummel_hfe This function is obsolete.

This function calculates forward gummel HFE for a 4 terminal device given Vbe, Vbc, and Ic. The HFE limit input limits HFE to the value entered. This is used to limit HFE in the region outside of the function's applicable range.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ic	Collector Current (A)
HFE Limit	Maximum HFE to be displayed.
Output:	Forward Gummel HFE

mxt4t_fwd_gummel_ib This function is obsolete.

This function calculates the forward gummel base current for a 4 terminal device given Vbe, Vbc, and Ic.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ic	Collector Current (A)
Output:	Forward Gummel Base current.

mxt4t_fwd_gummel_ic This function is obsolete.

This function calculates forward gummel collector current for a 4 terminal device given Vbe and Vbc.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Output:	Forward Gummel Collector current.

mxt4t_fwd_gummel_vbe This function is obsolete.

This function calculates forward gummel base-emitter voltage for a 4 terminal device given Ib and Ic.

Input Arguments:

ib	Base current (A)
Ic	Collector Current (A)
Output:	Forward Gummel Vbe.

mxt4t_i0 This function is obsolete.

This function extracts either IE0, IC0 or IB0 depending on which Output mode is selected: E/C/B. The function requires a terminal current as input. This transform was written to make the subsequent optimizations, which require either IE0, IB0 or IC0, more robust. Sometimes the optimizer would have trouble converging to a proper solution if these currents were too far from their final values.

Input Arguments:

I Data (A)

Output: E, C, B

Output: IE0, IC0, IB0 depending on Output Argument

mxt4t_linear_range This function is obsolete.

This function calculates the 2nd derivative of a dataset. It enables the user to see where the data is linear. This is useful in determining the valid range of mextram functions.

Input Arguments:

Y Data	unitless
X Data	unitless (must be uniform steps)
Smooth Points	number of points on either side of data point to be use for smoothing. 0 = disable
Smooth Iter	number of iterations that smoothing algorithm is performed on data. 0 = disable
Log Data ?	Log the data before the smoothing or derivative functions are applied
Output:	2nd derivative of the Y Data.

mxt4t_output_ic This function is obsolete.

This function calculates collector current output characteristics given Vce, Ic, Ib, and Vb. It is intended to model the quasi-saturation region of the transistor.

Input Arguments:

Vce	Vce Voltage (V)
Ic	Collector Current (A)
Ib	Base Current (A)
Vb	Base Voltage (V)
Output:	Collector Current

mxt4t_output_vbe This function is obsolete.

This function calculates base-emitter voltage Vce, Ic, Ib, and Vb. It is used to estimate the thermal resistance of the device.

Input Arguments:

Vce	Vce Voltage (V)
Ic	Collector Current (A)
Ib	Base Current (A)
Vb	Base Voltage (V)
Output:	Base Emitter Voltage

mxt4t_rev_early_ie This function is obsolete.

This function calculates the reverse early emitter current for a 4 terminal device given Vbe and Vbc.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Output:	Reverse Early emitter current.

mxt4t_rev_early_qb0_guess This function is obsolete.

This function calculates QBO based on the following formula:

QBO = IE0*(1-XCJE)*CJE*(dvbe/die @ vbe=0)

The function requires ie and vbe as inputs and the model parameters mex.CJE, mex.XCJE and the model variable IE0.

This transform was written for 2 reasons: (1) the optimization used to determine its final value can get lost if the initial value is way off; (2) The value of QBO is used to determine the initial values of other parameters. Therefore, the more accurate the value of QBO the more accurate these other parameters will be.

Input Arguments:

Vbe	Vbe Voltage (V)
Ie	Emitter Current (A)
Output:	QB0

mxt4t_rev_gummel_hfc This function is obsolete.

This function calculates the reverse gummel HFC for a 4 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ic	Emitter Current (A)
Substrate (Y/N)	Y -> Includes ibSub when Calculating hfc. N -> Excludes ibSub when Calculating hfc.
Output:	Reverse Gummel HFC.

mxt4t_rev_gummel_hfc_sub This function is obsolete.

This function calculates the HFC of the parasitic substrate transistor for a 4 terminal device given Vbe and Vbc.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Output:	Reverse Gummel substrate HFC.

mxt4t_rev_gummel_ib This function is obsolete.

This function calculates the reverse gummel base current for a 4 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ie	Emitter Current (A)
Output:	Reverse Gummel Base current.

mxt4t_rev_gummel_ie This function is obsolete.

This function calculates the reverse gummel emitter current for a 4 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ie	Emitter Current (A)
Output:	Reverse Gummel Emitter current.

mxt4t_rev_gummel_is This function is obsolete.

This function calculates the reverse gummel substrate current for a 4 terminal device given Vbe, Vbc, and Ie.

Input Arguments:

Vbe	Vbe Voltage (V)
Vbc	Vbc Voltage (V)
Ie	Emitter Current (A)
Output:	Reverse Gummel substrate current.

NOISE_1f_bjt_1Hz For each noise trace this function calculates the 1 Hz intercept point by calculating the average noise in the specified frequency range. The frequency range can be specified by using the variables X_LOW and X_HIGH. If N is the number of noise traces, the function returns an output dataset of size N filled with the N intercept points (one for each trace).

Inputs:

Frequency:	Frequency point dataset. Size: N*freqpoints.
Noise at constant Vc:	dataset containing the noise for the N traces. Size: N*freqpoints
Output:	Dataset filled with the N 1Hz interception points. Size: N.

Examples:

This transform is used during 1/f noise parameters extraction for bipolar devices. See model file *examples/model_files/noise/1_f_toolkit/bjt_1f_noise.mdl* The transform is used in the setup modeling/extract

NOISE_1f_bjt_calc This function calculates the current noise density at the device output (collector) given the frequency range, the device current gain Beta, the base current and the parameters Af and Kf listed in the Parameters table. The Noise is calculated as follows:

<Sic>= Kf * (ib^Af)/f * Beta^2

If N is the number of traces (number of DC bias points) the inputs are defined as follows:

Inputs:

Beta:	Dc current gain dataset. Size: N
frequency:	Frequency point dataset. Size: N*freqpoints.
Base Current:	Base current dataset. Size: N.
Output:	Dataset filled with the calculated noise. Size: N*freqpoints.

Examples:

This transform is used during 1/f noise parameters extraction for bipolar devices. See model file *examples/model_files/noise/1_f_toolkit/bjt_1f_noise.mdl* The transform is used in the setup modeling/extract

NOISE_1f_bjt_extract This function extracts the parameters Af and Kf. If N is the number of noise traces at a given Vc, inputs and output are as follows:

Inputs:

Beta:	Dc current gain dataset. Size: N.
Ic noise 1 Hz:	1 Hz intercept dataset. Size: N.
Base Current:	base current at each bias point. Size: N.
Output:	Return a dataset of size N with the calculated 1 Hz values using the extracted Af and Kf.
Extracts:	Af, Kf

Examples:

This transform is used during 1/f noise parameters extraction for bipolar devices. See model file *examples/model_files/noise/1_f_toolkit/bjt_1f_noise.mdl* The transform is used in the setup modeling/extract

NOISE_1f_force_bias This function forces a current or a voltage from the specified unit of a 4142B or 4156B/C.

NOTE The instrument will continue to force the bias until the function NOISE_1f_stop_bias is called.

Variables:

GPIB Address:	instrument address.
Compliance:	voltage or current compliance.
Value:	voltage or current value to be forced.

Parameters:

Bias source:	specify DC Bias Source Type (4142/4156).
GPIB Interface:	interface name.

Unit Slot (4142) or SMU (4156)

Force Current (I) or Voltage (V).

Examples:

ret = NOISE_1f_force_bias(29, 2, 25e-6, “4142”, “hpib”, “2”, “I”) this forces 25 µA of current from unit source on slot 2 of the 4142 at address 29. The interface name is “hpib” and the voltage compliance is 2 V.

This transform is used during 1/f noise parameters extraction for bipolar and MOS devices. See model file *examples/model_files/noise/1_f_toolkit/bjt_1f_noise.mdl* The transform is used in the setup measure/Noise. It is called by the GUI interface function btMeasure located in the setup GuiDriver/MeasureNoise.

NOISE_1f_get_Af This function returns the value of the parameter Af/AF/af stored in the parameter list.

Syntax

```
x = NOISE_1f_get_Af()
```

NOISE_1f_get_Bf This function returns the value of the parameter Bf/BF/bf stored in the parameter list.

Syntax

```
x = NOISE_1f_get_Bf()
```

NOISE_1f_get_Kf This function returns the value of the parameter Kf/KF/kf stored in the parameter list.

Syntax

```
x = NOISE_1f_get_Kf()
```

NOISE_1f_get_Ef This function returns the value of the parameter Ef/EF/Ef stored in the parameter list.

Syntax

```
x = NOISE_1f_get_Ef()
```

NOISE_1f_mos_1Hz For each noise trace this function calculates the 1 Hz intercept point by calculating the average noise in the specified frequency range. The frequency range can be specified by using the variables X_LOW and X_HIGH. If N is

the number of noise traces, the function returns an output dataset of size N filled with the N intercept points (one for each trace).

Inputs:

Frequency:	Frequency point dataset. Size: N*freqpoints.
Noise at constant Vd:	dataset containing the noise for the N traces. Size: N*freqpoints
Output:	Dataset filled with the N 1Hz interception points. Size: N.

Examples:

This transform is used during 1/f noise parameters extraction for MOS devices. See model file *examples/model_files/noise/1_f_toolkit/mos_1f_noise.mdl* The transform is used in the setup modeling/extract

NOISE_1f_set_Af This function sets the value of the parameter Af/AF/af in the parameter list.

Syntax

```
NOISE_1f_set_Af(value)
```

NOISE_1f_set_Bf This function sets the value of the parameter Bf/BF/bf in the parameter list.

Syntax

```
NOISE_1f_set_Bf(value)
```

NOISE_1f_set_Ef This function sets the value of the parameter Ef/EF/ef in the parameter list.

Syntax

```
NOISE_1f_set_Ef(value)
```

NOISE_1f_set_Kf This function sets the value of the parameter Kf/KF/kf in the parameter list.

Syntax

```
NOISE_1f_set_Kf(value)
```

NOISE_1f_stop_bias This function stops the bias from the specified DC source. It is used in conjunction with the NOISE_1f_force_bias.

Variables:

GPIB Address:	instrument address.

Parameters:

Bias source:	specify DC Bias Source Type (4142/4156).
GPIB Interface:	interface name.

Unit Slot (4142) or SMU (4156).

Examples:

ret = NOISE_1f_force_bias(29, “4142”, “hpib”, “2”) the SMU unit at slot 2 of the 4142 at address 29 will stop any voltage or current bias.

This transform is used during 1/f noise parameters extraction for bipolar and MOS devices. See model file *examples/model_files/noise/1_f_toolkit/bjt_1f_noise.mdl* The transform is used in the setup measure/Noise. It is called by the GUI interface function btMeasure located in the setup GuiDriver/MeasureNoise.

Optimize The IC-CAP general purpose optimizer. Performs Levenberg-Marquardt optimization, random optimization, hybrid optimization, and sensitivity analysis. The optimizer is described in Chapter 7, “Optimizing,” in the *User’s Guide*.

Input Arguments:	None
Output:	Levenberg-Marquardt: array of real, length 2 (RMS error, max error)
Random or Hybrid:	Array of real, length 1 (RMS error)

Sensitivity:	Nx1 matrix of real numbers; size determined by inputs.
Automatic Invocation:	By Optimize menu function (or Extract menu function when the *Extract Flag* option is set to Yes)

Package A utility function that can either “embed or de-embed” the effects of a package from S-parameter data provided as input. The resultant set of S-parameters is returned as a data set with the same frequency and bias conditions as the input S-parameter data set.

Usage	Package(S_parameter_data_set, embed/dEEmbed_flag, Z1, D1, L1a, L1b, L1m, C1m, C1, C12, Z3, D3, L3, Z2, D2, L2a, L2b, L2m, C2m, C2)

The package topology used here is a very simple series shunt representation of a component’s package. This package is more general purpose than EEfet3_package, EEbjt2_package, or EEmos1_package. Each port of this package has a transmission line that represents the package lead frame. Then a “T” network is defined on the input and output (port 1 and 2) that represents bond wires and can be used to model simple matching networks used in some pre-matched devices. This network is not included on the common lead. So working from the outside edge of the package’s input port (port 1) there is an ideal transmission line (Z1, D1), followed by the bonding/matching network.

L1a + L1b represent the bond inductance of the input port. The inductance is split into 2 parts. In a pre-matched device L1a is the bond inductance from the lead frame of port 1 to the shunt matching capacitor (modeled by L1m, C1m). L1b would be the bond wire from the top of the matching capacitor to the gate/base of the transistor. C1, C12, and C2 are fringing capacitors that encircle the intrinsic device (usually small values 20-30ff).

In the case of a transistor with no pre-matching, L1m, C1m and L1b would be set to zero. The “common” node of the input matching capacitor C1m and the output matching capacitor C2m is where transmission line and bond inductance of the common lead join.The intrinsic S-parameters used as input/output are connected at the “internal” side of L1b, L2b and L3.The output port (port 2) is an exact duplication of the input port. The transmission line (Z2, D2) represents the lead frame. The output matching/ bonding network is modeled with L2a, L2b and L2m, C2m.

All 3 of the transmission lines are ideal lines modeled with a characteristic impedance and length. The length is in units of meters.

Because you must use the same values for each of these arguments in many places in the IC-CAP model file, this function is constructed to use model variables as arguments. First: create 1 variable, in the model variable table, for each of the function arguments (thus making it global to the entire model in use). Then use the variables each time the function is used. In this manner you can ensure that the same values are being used to embed the model as were extracted from measurements.

The first argument is the data set upon which the function will operate. The second argument is a text string or variable containing a text string “embed” or “de-embed.” The function will operate on the input data set as indicated by the second argument.

PEL example that de-embeds a package from a measurement (based on first defining the following variables in the system variable table):

flag = “deembed”	Z1 = 50	D1 = 250e-6
L1a = 0.9e-9	L1b = 0	L1m = 0
C1m = 0	C1 = 20e-15	C12 = 20e-15
Z3 = 50	D3 = 0	L3 = 0.15e-9
Z2 = 25	D2 = 500e-6	L2a = 0.33e-9

L2b = 0 L2m = 0 C2m = 0

```
s_intrinsic = Package(meas_spars, flag, Z1, D1, L1a, L1b,
L1m, C1m, C1, C12, Z3, D3, L3, Z2, D2, L2a, L2b, L2m, C2m,)
```

PB_abort Karl Suss Prober function. Returns prober to local mode.

Input Arguments: None

Output: Array of 3 values:
output[0]= 0 if command succeeded, else returns error code.
output[1]= Column of current die location, else returns -999.999
output[2]= Row of current die location, else returns -999.999

Example:

```
result = PB_abort()
```

PB_bincode Karl Suss Prober function. Sets the Bincode of the current die location.

Input Arguments:

Reals or Integers: binvalue

Output: Single value
output[0]= 0 if command succeeded, else returns error code.

Example:

```
result=PB_bincode(binvalue)
```

PB_bindex Karl Suss Prober function. Sets the Bincode of the current die location, then steps (index) to the next testable die location (as defined by the pbench wafer map).

Input Arguments:

Reals or Integers: bin value

Output: Array of 3 values
output[0]= 0 if command succeeded, else returns error code.
output[1]= Column of new die location, else returns -999.999
output[2]= Row of new die location, else returns -999.999

Example:

```
result=PB_bindex(binvalue)
```

PB_bindex_cr Karl Suss Prober function. Sets the Bincode of the current die location, then moves the prober to the absolute column and row location specified.

Input Arguments:

Reals or Integers: bin value, column value, row value

Output: Array of 3 values
output[0]= 0 if command succeeded, else returns error code.
output[1]= Column of new die location, else returns -999.999
output[2]= Row of new die location, else returns -999.999

Example:

```
result=PB_bindex_cr(binvalue,column,row)
```

PB_gindex_cr Karl Suss Prober function. Return the current die index location from the wafer map.

Input Arguments: None

Output:	Array of 4 values output[0]= column (die) if command succeeded, else returns error code. output[1]= row (die) output[2]= X location (from home, absolute) output[3]= Y location (from home, absolute)

Example:

```
result=PB_gindex_cr()
```

PB_gsite_xy Karl Suss Prober function. Return the x and y location (in tenths of microns) of the current subsite.

Input Arguments:	None
Output:	Array of 2 values output[0]= Subsite x value output[1]= Subsite y value

Example:

```
result=PB_gindex_xy()
```

PB_index Karl Suss Prober function. Steps (index) to the next testable die location (as defined by the pbench wafer map).

Input Arguments:	None
Output:	Array of 3 values output[0]= 0 if command succeeded, else returns error code. output[1]= Column of new die location, else returns -999.999 output[2]= Row of new die location, else returns -999.999

Example:

```
result = PB_index()
```

PB_index_cr Karl Suss Prober function. Moves the prober to the absolute column and row location specified.

Input Arguments:

Reals or Integer:	Column value, Row value
Output:	Array of 3 values output[0]= 0 if command succeeded, else returns error code. output[1]= Column of new die location, else returns -999.999 output[2]= Row of new die location, else returns -999.999

Example:

```
result=PB_index_cr(column,row)
```

PB_msite_xy Karl Suss Prober function. Moves the prober to subsite location x, y (in tenths of microns).

Input Arguments:

Reals or Integer:	x value, y value
Output:	Output: Array of 3 values output[0]= 0 if command succeeded, else returns error code. output[1]= Subsite x coordinate, else returns -999.999 output[2]= Subsite y coordinate, else returns -999.999

Example:

```
result=PB_msite_xy(x,y)
```

PBench_CMD Karl Suss Prober function. Sends a user-specified command to the prober.

Input Arguments:

String:	Arbitrary string name to identify calling function Suss Prober command
Output:	output[0]= 0 if command succeeded, else returns error code.

Example:

```
result=PBench_CMD("Myfunction", "StepNextDie")
```

Pdown Wafer prober function. Lowers the chuck of the wafer prober. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	None
Output:	Single number with exit status
Automatic Invocation:	None

Phome Wafer prober function. Used for loading a wafer onto the chuck and moving it to the home position. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	None
Output:	Single number with exit status
Automatic Invocation:	None

Pimove Wafer prober function. Moves the chuck a relative increment from its current position. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:

Reals or Integers:	X Delta, Y Delta
Output:	Single number with exit status

Automatic Invocation: None

Pink Wafer prober function. Calls the inker function of the prober if it is supported. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:
- Reals or Integers: Inker Num

Output: Single number with exit status

Automatic Invocation: None

Pmove Wafer prober function. Moves the chuck to an absolute position. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:
- Reals or Integers: X Position, Y Position

Output: Single number with exit status

Automatic Invocation: None

PNCAPsimu

Calculates P-N Junction capacitance versus voltage. Can be used as a quick simulation. The proper parameter names must be specified as inputs.

Input Arguments:
- Data Sets: Junction V
- Reals or Integers: CJ Param, VJ Param, MJ Param

Output: Array of real numbers; size determined by inputs

Porig Wafer prober function. Defines the current X & Y position of the chuck. Must be called before calling the Pmove or Pimove functions. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	
Reals or Integers:	X Origin, Y Origin
Output:	Single number with exit status
Automatic Invocation:	None

Ppos Wafer prober function. Returns the current X & Y position of the chuck. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	None
Output:	Array of 2 points: x and y
Automatic Invocation:	None

Prober_debug Wafer prober function. Used to turn the debug and macro stop (on error) flags on and off. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	
Reals or Integers:	Debug Flag, Stop Flag
Output:	Single number with exit status
Automatic Invocation:	None

Prober_init Wafer prober function. Initializes the prober for use. This function must be called before any other prober functions are used in the Macro. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	
Reals or Integers	Bus Address, Orientation
Strings/Pars/Vars	Prober Type, Device File
Output:	Single number with exit status
Automatic Invocation:	None

Prober_reset Wafer prober function. Sends a device clear command to the prober. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	None
Output:	Single number with exit status
Automatic Invocation:	None

Prober_status Wafer prober function. Sends a query to the prober to obtain the Remote/Local control state and the edge sensor contact state. The prober should be initialized with *Prober_init* before this function. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	None
Output:	Array of 3 points: x and y and z
Automatic Invocation:	None

Program or Program2 The Program2 function is the recommended way to define a program in IC-CAP's Parameter Extraction Language over the older Program function. Program2 provides improved function argument/parameter management and improves access to IC-CAP variables.

Both Program and Program2 functions provide a text editor in which a program can be written in IC-CAP's Parameter Extraction Language to carry out simple or complicated

computations. When a *RETURN* statement is used, the computed results are available for use in Plots, other Transforms, and table elements throughout IC-CAP. Both functions can also execute most IC-CAP menu functions using an *iccap_func* call. Both functions also provides features enabling users to write custom extraction routines and assign new Model parameter values.

Refer to Chapter 9, “Parameter Extraction Language,” in this manual, and to Chapter 9, “Using Transforms and Functions” in the *User’s Guide,* for more information.

If GET_INT, GET_REAL, GET_STRING or LINPUT is used in a Program or Macro to pass parameters, all GET_INT statements should be located immediately at the start of the Program or Macro along with any other GET_INT, GET_REAL, GET_STRING or LINPUT statements. Once any other ICCAP_FUNC statement is invoked, the list of anticipated arguments is reset, thereby removing all the extra arguments from the calling ICCAP_FUNC statement. The Program2 function does not have these limitations.

The statement GET_DATASET can be used to redirect passed Program2 function parameter dataset arguments to local variables of a Program2 function. GET_DATASET is not supported with Program or Macro functions—it is only currently supported with the Program2 function.

If GET_INT, GET_REAL, GET_STRING or LINPUT statements are used in a Program or Macro to pass parameters, those input statements search the passed parameter list until they find a valid passed parameter argument of the expected type. In the Program2 function, the GET_DATASET, GET_INT, GET_REAL, GET_STRING or LINPUT statements will only try to evaluate the next available passed function parameter as a value of the expected type, and will error out if the next passed function parameter is not able to be evaluated as a value of the expected type.

In the Program2 function, all variables are automatically treated as local variables unless those variables are first explicitly declared as global variables using the GLOBAL_VAR statement. Before using a variable from a variable table in

Program2, you should declare the variable as global with the GLOBAL_VAR statement. In Program and Macro functions, all variables can be resolved globally or locally without needing to explicitly specify which variables are global using the GLOBAL_VAR statement.

Input Arguments:	None (input statements and data are supplied interactively into a dedicated text editor)
Output:	Complex array or matrix array. Size and type depends on the arguments to a RETURN statement in program text. The size will be 1 if return data is returned by a RETURN_VALUE statement. In the absence of an appropriate RETURN statement there is no output data set.
Extracts:	Both functions permit the extraction of any combination of Model parameters, DUT parameters, and IC-CAP system variables.
Automatic Invocation:	For both functions, several possibilities exist

- If a program uses the *RETURN* statement to generate a data set, and 1 of the data sets used within the program changes (due to a simulation, for example), then the program is automatically invoked, so that its returned data set is refreshed.
- If a program assigns new values to Model or DUT parameters, then the program is considered an extraction function, and Automatic Invocation occurs when the *Extract* command is issued for the associated Setup or DUT.

  These rules are mutually exclusive, and the second one takes higher precedence. When neither rule is satisfied, no Automatic Invocation occurs. Some statements allow

direct control over these rules, for example, UPDATE_MANUAL. For more information, refer to "Automatic Transform Execution" in the *User's Guide*.

Pscale Wafer prober function. Defines the X & Y stepping dimensions used by the Pmove and Pimove functions. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:

Reals or Integers:	X Size [um], Y Size [um]
Output:	Single number with exit status
Automatic Invocation:	None

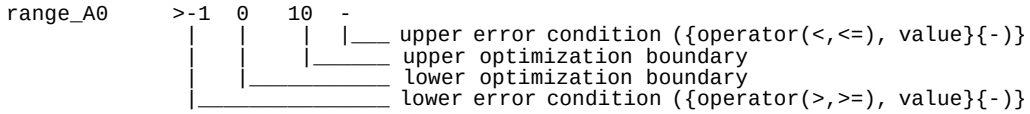
PSP_DC_vth Picks up one single sweep curve of id=f(vg) of a specified setup and extracts the threshold voltage vth. The setup is specified by the parameters path to vd, ... etc. This makes it easier to call the function with variable inputs inside the PEL programs.

The 'Flag' variable is used to define certain conditions, for example, the extraction of vth for the large device that does not need to calculate all the early voltage values.

Input Arguments:

Variables:	Length (L) Total gate width (W) Number fingers (NF) Flag for extraction options flag: 1 Fixed Id(Vth) = Idref*L/W 2 Fixed Id(Vth) = Idref*NF* ((W/NF)-2*Delta_W)/ (L-2*Delta_L) Reference current Idref for extraction options Delta L (one side) Delta W (one side) # of curve Type (1=NMOS, -1=PMOS) Debug (1: show internal states of the function 0: nothing)
Parameters:	path to setup vd vg vb id type id (M,S) version
Output:	Value vth or failure indicator
Extracts:	Vth (1e99 indicates error)

PSP_check_par Checks whether a model parameter is in a predefined range. The range information for this parameters must be given in a variable in the referenced path. The range information is stored in a string in the following format:



Input Arguments:

Variables:	Actual value of parameter to check
Parameters:	Parameter name Path to parameter range definition
Output:	Flag for correct operation: 0: parameter is in specified range –1: parameter is outside specified range –2: error during function execution (e.g., variable 'range_xx' not found)

PSP_DC_calc_bin_parameter Calculates from the input the four binning parameters P0, PL, PW and PP. If the calculation is done correctly, outputs[0] will return 0. Otherwise, outputs[0] will result in a negative number. In such a case, the error will be printed in detail in the output window.

Input Arguments:

Inputs:	Array with 4 parameters P1 .. P4 of the bin corners Array with 4 gate lengths L1 .. L4 of the bin corners Array with 4 gate widths W1 .. W4 of the bin corners
Variables:	PSP binning type
Output:	Array containing error condition and binning parameters outputs[0] = error condition (0=o.k., any other number indicates an error) outputs[1] = P0<par>, e.g. POVFB outputs[2] = PL<par>, e.g. PLVFB outputs[3] = PW<par>, e.g. PWVFB outputs[4] = PLW<par>, e.g. PLWVFB
Extracts:	Binning parameters P0<par>, PL<par>, PW<par>, PLW<par>

PSP_set_opt Accepts a list of model parameters, separated by blanks and searches the range information for these parameters in the range_<PARAMETER> variables in the referenced path.

After analyzing the range information for each parameter, the variables min_<PARAMETER> and max_<PARAMETER> in the local setup/DUT are set. These variables can be used as upper/lower limit in an optimizer call.

The range information is stored in a string in the following format:

```
range_A0     >-1  0   10  -
|    |     |  |___ upper error condition ({operator(<,<=), value}{-)}
|    |     |______ upper optimization boundary
|    |____________ lower optimization boundary
|_________________ lower error condition ({operator(>,>=), value}{-)}
```

Input Arguments:

Parameters:	Parameter names, separated by blanks Path to parameter range definition
Output:	Flag for correct operation: 0: everything is ok -1: error during function execution (e.g., variable 'range_xx' not found)

Example call in PEL:

```
erg = PSP_set_opt("RDSW PRWG
       PRWB","Extraction_configuration/Boundaries")
```

PTFTCV_cgd This function is obsolete.

Standard extraction for the UCB p-Si TFT model. Extracts p-Si TFT gate-to-drain overlap capacitance and a transition parameter.

Input Arguments:

Data Sets:	Gate-Drain V, Source-Drain V, Gate-Drain C
Output:	None
Extracts:	CGDO, ACGD
Automatic Invocation:	By Extract menu function

PTFTCV_cgs This function is obsolete.

Standard extraction for the UCB p-Si TFT model. Extracts p-Si TFT gate-to-source overlap capacitance and transition parameters.

Input Arguments:

Data Sets:	Gate-Source V, Drain-Source V, Gate-Source C
Output:	None
Extracts:	CGSO, ACGS, VGTRANLC, VGTRANHC
Automatic Invocation:	By Extract menu function

PTFTDC_lin This function is obsolete.

Standard extraction for the p-Si TFT model. Extracts linear region parameters using Id versus V_g data measured on a p-Si TFT device.

Input Arguments:

Data Sets:	Drain V, Gate V, Source V, Drain I
Output:	None
Extracts:	VTO, U0, U1, U2, U3, U4, SUBSLOPE, VOFF, THERMALI, VGTRANL, VGTRANH, GIDLA, GIDLB
Automatic Invocation:	By Extract menu function

PTFTDC_sat This function is obsolete.

Standard extraction for the p-Si TFT model. Extracts saturation region parameters using Id versus Vd data measured on a p-Si TFT device.

Input Arguments:	
Data Sets:	Drain V, Gate V, Source V, Drain I
Output:	None
Extracts:	VMAX, L2, PHITA, S1, S2
Automatic Invocation:	By Extract menu function

Pup Wafer prober function. Moves up the chuck of the wafer prober. For more information regarding this function, refer to "External Prober User Functions" on page 155.

Input Arguments:	None
Output:	Single number with exit status
Automatic Invocation:	None

rand_flat Returns a single random number generated for each call between 0.0 and 1.0 inclusive. Use *rand_seed()* to set a seed value. This is a 32-bit random number generator of Park and Miller with Bays-Durham shuffle to exclude serial correlations. The period is larger than 1E08.

Input Arguments:	None
Output:	Single real number
Automatic Invocation:	None

Example:

- Example PEL code:

```
! create 100 random numbers between
! lower bound and upper bound
! ex. 100 random real numbers from 1.0 to 10.0
```

```
complex num[100]
! sets a varying random seed for all successive calls
!  to rand_flat()
x=rand_seed(val(system$("date +%s")))

lowerbound=1.0
upperbound=10.0
i=0
while i<100
  num[i]=rand_flat()*(upperbound-lowerbound)+lowerbound
  i=i+1
endwhile
```

- To view an example of the random functions used in a setup to generate random numbers, view the *random_example.mdl* example discussed in the *User's Guide,* Chapter 12, “Creating Graphic User Interfaces”, “Random Numbers (Example),” section.

rand_gauss Returns a random number generated for each call that follows a normal distribution with the given mean and sigma values. Use *rand_seed()* to set a seed value. This is a 32-bit random number generator of Park and Miller with Bays-Durham shuffle to exclude serial correlations. The period is larger than 1E08.

Input Arguments:

Reals or Integers:	Mean, Sigma
Output:	Single real number
Automatic Invocation:	None

Example:

- Example PEL code:

```
! Creates 100 random numbers within a
! gaussian distribution with a mean of
! approximately 5 and a standard deviation
! of approximately 1

complex num[100]
! sets a varying random seed for all successive calls
!  to rand_gauss(…)
x=rand_seed(val(system$("date +%s")))

i=0
while i<100
  num[i]=rand_gauss(5,1)
  i=i+1
endwhile
```

- To view an example of the random functions used in a setup to generate random numbers, view the *random_example.mdl* example discussed in the *User's Guide,* Chapter 12, “Creating Graphic User Interfaces”, “Random Numbers (Example),” section.

rand_seed Sets a seed for the internal random number generator that has the initial seed of 3300. The *rand_seed(seed)* function should be used to set the seed for the internal random number generator for all successive calls to the *rand_flat()* or *rand_gauss()* functions. This is a 32-bit random number generator of Park and Miller with Bays-Durham shuffle to exclude serial correlations. The period is larger than 1E08.

Input Arguments:

Reals or Integers:	Seed (must not be zero)
Output:	None
Automatic Invocation:	None

Example:

- Using a specific/fixed seed value with *rand_flat()* or *rand_gauss()*.

  You can input a fixed seed value for the *rand_seed(seed)* function.

  For example:

```
x=rand_seed(42)
y1=rand_flat() or y1=rand_gauss(gaussMean, gaussSigma)
y2=rand_flat() or y2=rand_gauss(gaussMean, gaussSigma)
```

  where *y1* will equal a first random number and *y2* will equal a second random number and *y1* may not necessarily equal *y2*.

  If you set the same fixed seed value again and call *rand_flat()* or *rand_gauss*(*gaussMean*, *gaussSigma*) again.

  For example:

```
x= rand_seed(42)
y1=rand_flat() or y1=rand_gauss(gaussMean, gaussSigma)
x= rand_seed(42)
y2=rand_flat() or y2=rand_gauss(gaussMean, gaussSigma)
```

where *y1* == *y2* since the seed was set to the same fixed seed before each call.

Since *rand_flat()* or *rand_gauss()* return a single random number, each time you call *rand_seed(42)* beforehand you will get the same single random number.

- Generating a varying seed value based on the current time with *random()*.

  Instead of using the same fixed seed number each time to generate a random number, another approach would be to create a varying real number seed out of the current time.

  For example:

```
x = rand_seed(val(system$("date + %s")))
y1 = rand_flat() or y1 = rand_gauss(gaussMean, gaussSigma)
y2 = rand_flat() or y2 = rand_gauss(gaussMean, gaussSigma)
```

  where y1 will equal a first random number and y2 will equal a second random number and y1 may not necessarily equal y2.

  If you were to call rand_seed(val(system$("date + %s"))) again later before another call to rand_flat() or rand_gauss(...) the random seed value would have been set differently each time so the calls to rand_flat() or rand_gauss() would still return different random values.

```
x= rand_seed(val(system$("date + %s")))
y1=rand_flat() or y1=rand_gauss(gaussMean, gaussSigma)
x= rand_seed(val(system$("date + %s")))
y2=rand_flat() or y2=rand_gauss(gaussMean, gaussSigma)
```

  where y1 will equal a first random number and y2 will equal a second random number and y1 may not necessarily equal y2.

- To view an example of the random functions being used in a Setup to generate random numbers, view the *random_example.mdl* example discussed in the *User's Guide,* Chapter 12, “Creating Graphic User Interfaces”, “Random Numbers (Example),” section.

random Creates a data set of random numbers with values between 0 and 1. This function is based on the underlying C code for *srand48* and *rand48*. This function will return a dataset of 'N' numbers where N is the size defined by the

current Setup's input sweeps. This function is referred to data in an IC-CAP DUT Setup that includes a defined input set that evaluates to a specific number of points.

Input Arguments:	
Reals or Integers:	Seed
Output:	Array of real numbers; size determined by setup
Automatic Invocation:	On Data Set Input Change

Example:

- Using a specific/fixed seed value with random(seed).

  You can call the random(seed) function with a specific seed value.

  For example:

  ```
  random(49)
  ```

  Also, say that the IC-CAP DUT Setup in which you are calling the IC-CAP "random" function (transform is defined in your DUT Setup's "Extract / Optimize" tab) has 100 points in your DUT Setup's "Measure / Simulate" tab, then the result of running the random(seed) function will also evaluate to 100 numbers in the resulting random number dataset. However, each time you call the random(49) function, you'll get the same 100 random numbers because they're all starting with the same seed number (example random(49) has seed = 49).

- Generating a varying seed value based on the current time with random(seed).

  Instead of using the same seed number all the time to generate a random number, another approach would be to create a varying real number seed out of the current time.

  For example:

  ```
  random(val(system$("date +%s")))
  ```

- To view an example of the random functions being used in a Setup to generate random numbers, view the *random_example.mdl* example discussed in the *User's Guide,* Chapter 12, “Creating Graphic User Interfaces”, “Random Numbers (Example),” section.

RBBcalc Used in extraction of base resistance parameters for the UCB Bipolar model. Calculates RBB from corrected H11 measurements generated with the *H11corr* function described above. A circle fit is performed on the complex data to extrapolate the high frequency real axis intercepts.

Input Arguments:

Data Sets:	H11
Output:	Array of complex numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

Example PEL Statement:

```
rbbcalc_data = RBBcalc(H11)
```

RMSerror Calculates the RMS error between 2 data sets. The error of the second input is calculated with respect to the first input. Returns the error in percent or magnitude. Three formulations are available depending on the value of the third argument labeled *% Err Flag*.

Input Arguments:

Data Sets:	Input 1, Input 2
Reals or Integers:	% Err Flag
Output:	Single real number
Automatic Invocation:	On Data Set Input Change

Example PEL Statement:

```
percent_error = RMSerror(ic.m,ic.s,1)
```

If 0 is passed as the third argument, the absolute value of the difference between the two datasets is returned.

$$\sqrt{\sum_{i=1}^{N} [(sim_i - meas_i)2]/N}$$

If 1 or 2 is passed as the third argument, a relative (or percent) error is calculated. For a value of 1, the error of the second input is calculated with respect to the first input for each point. If any values in the first dataset are 0, the function returns an error.

$$\sqrt{\sum_{i=1}^{N} [(sim_i - meas_i)/meas_i]^2/N}$$

For a value of 2, the same formulation used by the Levenberg-Marquardt optimizer is used. This is also a relative (or percent) error calculation, but the formulation takes the error relative to the larger of the two data set values on a point by point basis. This formulation always returns a value.

$$\sqrt{\sum_{i=1}^{N} [((sim_i - meas_i)/max(|meas_i|, |sim_i|))^2)]/N}$$

Where

sim_i = the i^{th} simulated data point

$meas_i$ = the i^{th} measured data point

N = the total number of data points

sin Sine of an angle in radians.

Input Arguments:

Data Sets: Input 1

Output: Complex number, matrix, complex array, or matrix array (depends on input argument)

Automatic Invocation: On Data Set Input Change

sinh Hyperbolic sine.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

smooth3 Returns 3-point running average of the Input data set. End points of each curve are not affected. Defined in *userc.c*.

Input Arguments:

Data Sets:	Input
Output:	Complex array or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

SPECSSpin Used in an IC-CAP Macro to determine the matrix connections of the device under test. *ICMSpin* returns the matrix pin number that corresponds to a specified terminal index on the device. This function only returns valid data when IC-MS test execution is running. Refer to the *IC-MS User's Manual* for more information on using *ICMSpin*.

Input Arguments:

Reals or Integers:	Terminal Index

Output:	Matrix pin number corresponding to the specified device terminal index
Automatic Invocation:	None

Example PEL Statement:

```
pin_num = ICMSpin(1)
```

sqrt Square root function. Note that sqrt(-1) correctly produces an imaginary result.

Input Arguments:	
Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

SWM_debug Switching matrix function. Turns the debug flag on and off. For more information regarding this function, refer to "External Matrix Driver User Functions" on page 166.

Input Arguments:	
Reals or Integers:	Debug Flag
Output:	Single number with exit status
Automatic Invocation:	None

SWM_init Switching matrix function. Initializes the switching matrix and clears all port and pin connections. This must be called before any other switching matrix functions are used in the Macro. For more information regarding this function, refer to "External Matrix Driver User Functions" on page 166.

Input Arguments:

Reals or Integers:	Block 1 Addr, Block 2 Addr
Strings/Pars/Vars:	Matrix Type, Device File
Output:	Single number with exit status
Automatic Invocation:	None

tan Tangent of an angle in radians.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

tanh Hyperbolic tangent.

Input Arguments:

Data Sets:	Input 1
Output:	Complex number, matrix, complex array, or matrix array (depends on input argument)
Automatic Invocation:	On Data Set Input Change

TARGET_DC_vth Picks up one single sweep curve of *id=f(vg)* of a specified setup and extracts the threshold voltage *vth*. The setup is specified by the parameters path to *vd*, and so on. This makes it easier to call the function with variable inputs inside the PEL programs.

The *Flag* variable defines certain conditions, for example, the extraction of *vth* for the large, which does not need to calculate all the early voltages.

Input Arguments:

Variable	Length (L) Total gate width (W) Number fingers (NF) Flag for extraction options flag: 1 Fixed Id(Vth) = Idref*L/W 2 Fixed Id(Vth) = Idref*NF* ((W/NF)-2*Delta_W)/ (L-2*Delta_L) Reference current Idref for extraction options Delta L (one side) Delta W (one side) # of curve Type (1=NMOS, -1=PMOS) Debug (1: show internal states of the function 0: nothing)
Parameters:	path to setup vd vg vb id type id (M,S) version
Output:	Value vth or failure indicator
Automatic Invocation:	Vth (1e99 indicates error)

tis_p_down HP 4071A wafer prober function. Lowers the chuck of the wafer prober.

tis_p_home HP 4071A wafer prober function. Used for loading a wafer onto the chuck and moving it to the home position.

tis_p_imove HP 4071A wafer prober function. Moves the chuck a relative increment from its current position.

tis_p_ink HP 4071A wafer prober function. Calls the inker function of the prober if it is supported.

tis_p_move HP 4071A wafer prober function. Moves the chuck to an absolute position.

tis_p_orig HP 4071A wafer prober function. Defines the current X & Y position of the chuck. Must be called before calling the tis_p_move or tis_p_imove functions.

tis_p_pos HP 4071A wafer prober function. Returns the current X & Y position of the chuck.

tis_p_scale HP 4071A wafer prober function. Defines the X and Y stepping dimensions that are used by the tis_p_move and tis_p_imove functions.

tis_p_up HP 4071A wafer prober function. Moves up the chuck of the wafer prober.

tis_prober_get_ba HP 4071A wafer prober function. No Help Available.

tis_prober_get_name HP 4071A wafer prober function. No Help Available.

tis_prober_init HP 4071A wafer prober function. Initializes the prober for use. This function must be called before any other prober functions are used in the Macro.

tis_prober_read_sysconfig HP 4071A wafer prober function. No Help Available.

tis_prober_reset HP 4071A wafer prober function. Sends a device clear command to the prober.

tis_prober_status HP 4071A wafer prober function. Sends a query to the prober to obtain the Remote/Local control state and the edge sensor contact state. The prober should be initialized with tis_prober_init before this function.

TRL_Cal Deembed the raw measured data using measured data of TRL (thru-reflect-line) calibration standards. The function calculates the error coefficients and returns the corrected S-parameters data. The reference plane is defined at the middle of the thru standard, or at the interface to the DUT when it is installed in the compatible carrier.

Inputs:

Freq Data:	Frequency Inputs
S data:	Raw (uncalibrated) S-parameters
Thru:	measured S-parameters of the Thru standard
Short:	measured S-parameters of the Short standard
Line A:	measured S-parameters of Line A standard
Line B:	measured S-parameters of Line B standard
Line C:	measured S-parameters of Line C standard
Freq 1 Trans:	transition frequency Line A to Line B
Freq 2 Trans:	transition frequency Line B to Line C
Output:	Corrected (calibrated) S-parameters data

TwoPort Converts the data in a data set from one 2-port parameter type
(S, Y, H, Z, K, A) to another. Enter the name of the data set that is to be converted, the old 2-port type, and the new 2-port type. Use K for *Cascaded Scattering Matrix* and A for *ABCD Matrix*. Note: TWOPORT does not read TWOPORT_Z0 at execution time, only at measurement and simulation time.

Input Arguments:

Data Sets:	Input
Strings/Pars/Vars:	From [SYHZKA], To [SYHZKA]
Output:	Matrix array; size determined by inputs
Automatic Invocation:	On Data Set Input Change

Example PEL Statement:

```
h_dataset = TwoPort(s_dataset,"S","H")
```

TwoPort2 Same as TwoPort function except the characteristic impedance, Z0, is an input parameter. This allows execution-time conversion of 2-port data to a new Z0.

Input Arguments:

Data Sets:	Input
Reals or Integers:	Z0
Strings/Pars/Vars:	From (SYHZKA) To (SYHZKA)
Output:	Matrix array; size determined by inputs
Automatic Invocation:	On Data Set Input Change

Example PEL Statement:

```
h_dataset = TwoPort2(s_dataset,75,"S","H")
```

USERC_avg_2 Averages 2 DC data sets, point-by-point. Provided as an example of a math function implemented in User C code. The source code is in *$ICCAP_ROOT/src/userc.c*.

Input Arguments:

Data Sets:	Data 1, Data 2
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

USERC_avg_3 Averages 3 DC data sets, point-by-point. Provided as an example of a math function implemented in User C code. The source code is in *$ICCAP_ROOT/src/userc.c*.

Input Arguments:	
Data Sets:	Data 1, Data 2, Data 3
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

USERC_close Closes an open file. See *USERC_open* for essential additional information about this function.

Input Arguments:	
Reals or Integers:	File Descriptor (generated by earlier *USERC_open call*)
Output:	0 or -1 (-1 indicates an error)
Automatic Invocation:	None

USERC_conjg Produces the conjugate of the input data set. This function is similar to the function named conjg, but is provided as an example of a User C math function manipulating complex numbers. The source code is in *$ICCAP_ROOT/src/userc.c*.

Input Arguments:	
Data Sets:	Cplx DS
Output:	Complex number or array of complex numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

USERC_data_w_check Returns a complex number designated by a name, row, and column. Example of C library function d*ata_w_check()* in *userc.c*.

Input Arguments:

Reals or Integers:	Row, Col, Index, Data Set name, Type
Output:	A single complex number.
Automatic Invocation:	None

USERC_get_object_name If the variable name exists, returns the name of the calling Transform or Macro. Note that the leading / in the name is not returned.

Syntax

```
USERC_get_object_name(<varname>)
```

Where

<*varname*> is a string naming a variable in the variable table within the scope of the caller. This variable returns the names of the calling Transform or Macro.

Examples:

If macro */npn/tester* contains the following line:

```
x=USERC_get_object_name("objname")
```

And if *objname* is in the Model Variables or system variables, then it returns *npn/tester*.

If Transform /npn/dc/fgummel/tester contains the following line:

```
x=USERC_get_object_name("xformName")
```

And if *xformName* exists in the Setup Variables, DUT Variables, Model Variables, or System Variables, then it returns *npn/dc/fgummel/tester*.

USERC_init_param Demonstrates in C code how to assign a value to a model parameter, a DUT parameter, or an IC-CAP system variable. Demonstrates use of the User C utility function named *set_par_or_var()*. The source code is in the set_param function in *$ICCAP_ROOT/src/userc.c*.

Input Arguments:

Reals or Integers:	New Value
Strings/Pars/Vars:	Parameter to set (this should be the name of a model parameter, a DUT parameter, or an IC-CAP system variable)
Output:	None
Extracts:	N/A
Automatic Invocation:	By Extract menu function

USERC_num_of_points Returns the number of points for a given sweep. Example of C library function *get_num_of_points()* in *userc.c*.

Input Arguments:

Reals or Integers:	Sweep order, Sweep path
Output:	A positive real number, or -1 for error.
Automatic Invocation:	None

Example PEL Statement:

```
nop = USERC_num_of_points(1, "")
! A blank path is current Setup
```

USERC_open Accesses a disk file for reading, writing or both. For instrument control, use *HPIB_open()* and related *HPIB* functions. This function can be used in conjunction with *USERC_readnum, USERC_readstr, USERC_read_reals, USERC_seek, USERC_tell, USERC_write,* and *USERC_close* to perform I/O operations. A more complete description of these functions and examples of their use in performing I/O

operations with disk files are available in Appendix H, “User C Functions.” The source code for these functions is provided in *$ICCAP_ROOT/src/userc_io.c*.

Input Arguments:

Strings/Pars/Vars:	Filename, Access Mode
Output:	-1 on failure, or else a positive integer file designator that you should save to use with the other *User C I/O* functions mentioned in the description.
Automatic Invocation:	None

Example PEL Statement:

```
file_num = USERC_open("datafile","r") ! read access
```

USERC_read_reals Opens a file, reads and returns an array of real numbers, and closes the file. For additional information about this function, see Appendix H, “User C Functions.”

Input Arguments:

Strings/Pars/Vars:	Filename
Output:	Array of real numbers, with size determined by the Setup
Automatic Invocation:	None

Example PEL Statement:

```
data_array = USERC_read_reals("datafile")
```

USERC_readnum Reads 1 real number from an open file, 1.0E6, for example. See *USERC_open* for essential additional information about this function.

Input Arguments:

Reals or Integers:	File Descriptor (generated by earlier *USERC_open* call), Device File Flag
Strings/Pars/Vars:	Scanf Format
Output:	a real number (the value 9.99998E+37 means an error occurred)
Automatic Invocation:	None

Example PEL Statement:

```
VTO = USERC_readnum(file_num,0,"VTO = %lf")
```

USERC_readstr Reads a string from an open file and sets the specified IC-CAP variable equal to it. See *USERC_open* for essential additional information about this function.

Input Arguments:

Reals or Integers:	File Descriptor (generated by earlier *USERC_open* call), Device File Flag (use *1* if reading from an instrument driver device file, *0* if reading from an ASCII file)
Strings/Pars/Vars:	Scanf Format, Var Name
Output:	0 on success, or -1 on failure
Automatic Invocation:	None

Example PEL Statement:

```
! read and set SIMULATOR name from a file
read_result = USERC_readstr(file_num,0,"%s",
                            IC-CAP_variable)
```

USERC_seek Goes to a particular byte offset in an open file. See *USERC_open* for essential additional information about this function.

Input Arguments:

Reals or Integers:	File Descriptor (generated by earlier *USERC_open* call), Offset Value, Offset Type
Output:	0 on success, or -1 on failure
Automatic Invocation:	None

USERC_set_param Sets the parameter specified by the second argument to the value of the first argument.

Input Arguments:

Data Sets:	None
Reals or Integers:	Value of the parameter
Strings/Pars/Vars:	Name of the parameter to set
Output:	None
Automatic Invocation:	MANUAL

Example PEL Statement:

```
x = USERC_set_param(100,NPN,BF)
```

USERC_set_param_quiet set the value of a parameter or variable referenced by a string. Unlike USERC_set_param(), this version makes no output to the status window.

Example PEL Statement:

```
x=USERC_set_param_quiet(1e-15,"/npn/IS")
```

USERC_size Returns the array size of the data set whose name is given by a string.

Input Arguments:

Strings/Pars/Vars:	Data Set name
Output:	A positive real number.
Automatic Invocation:	None

Example PEL Statement:

```
data_size = USERC_size("id")
```

USERC_sweep_mode Returns the sweep mode for the input with sweep order N.

Usage:	x=USERC_sweep_mode(N, <path>)
Returns:	0 for V 1 for I 2 for T 3 for F 4 for P 5 for U 6 for W
Extracts:	Example C library function of get_sweep_mode() in userc.c. Use USERC_num_of_points() to check the existence of a sweep.

USERC_sweep_name Returns a sweep name through a variable. Example C library function of *get_sweep_name()* in *userc.c*. Use *USERC_num_of_points()* to check the existence of a sweep.

Input Arguments:

Strings/Pars/Vars:	Sweep order, Sweep path, Variable name
Output:	0 for success, -1 for error
Automatic Invocation:	None

Example PEL Statement:

```
x = USERC_sweep_name(1, "/npn/dc/fearly", "first_sweep")
```

USERC_sweep_start Returns a sweep start value. Example C library function of *get_sweep_start()* in *userc.c*. Use *USERC_num_of_points()* to check the existence of a sweep.

Input Arguments:

Strings/Pars/Vars: Sweep order, Sweep path

Output: 0 for error

Automatic Invocation: None

Example PEL Statement:

```
x = USERC_sweep_start(1, "/npn/dc/fearly")
```

USERC_sweep_stepsize Returns a (LIN) sweep step value. Example C library function of *get_sweep_stepsize()* in *userc.c*. Use *USERC_num_of_points()* to check the existence of a sweep.

Input Arguments:

Strings/Pars/Vars: Sweep order, Sweep path

Output: 0 for error

Automatic Invocation: None

Example PEL Statement:

```
x = USERC_sweep_stepsize(1, "/npn/dc/fearly")
```

USERC_sweep_stop Returns a sweep stop value. Example C library function of *get_sweep_stop()* in *userc.c*. Use *USERC_num_of_points()* to check the existence of a sweep.

Input Arguments:

Strings/Pars/Vars: Sweep order, Sweep path

Output: 0 for error.

Automatic Invocation: None

Example PEL Statement:

```
x = USERC_sweep_stop(1, "") ! within current Setup
```

USERC_system Demonstrates the invocation of an operating system command from User C code.

Input Arguments:	
Strings/Pars/Vars:	operating system command
Output:	Single number with exit status of the operating system command
Automatic Invocation:	None

USERC_tell Tells current byte offset in an open file. See *USERC_open* for essential additional information about this function.

Input Arguments:	
Reals or Integers:	File Descriptor (generated by earlier *USERC_open* call)
Output:	–1 on error, or else current byte offset into file
Automatic Invocation:	None

USERC_transpose Returns a data set of matrices, in which each of the input data set's matrices has been transposed. Provided as an example of a matrix math function implemented in User C code. The source code is in $ICCAP_ROOT/*src/userc.c*.

Input Arguments:	
Data Sets:	Matrix DS
Output:	Matrix or matrix array; size determined by inputs
Automatic Invocation:	On Data Set Input Change

USERC_write Prints any string expression into an open file, in ASCII. (To convert a number to a string expression, refer to the VAL$ function described in the "Built-in Functions" on page 712. Refer to USERC_open for additional essential information about this function.)

Input Arguments:

Reals or Integers:	File Descriptor (generated by *USERC_open* call), Device File Flag
Strings/Pars/Vars:	String to Write
Output:	0 or –1 (–1 indicates an error)
Automatic Invocation:	None

Example PEL Statement:

```
write_result = USERC_write(file_num,0,"VTO="&VAL$(VTO))
```

variance Calculates the statistical variance of a data set. Adequate for a real or complex data set, but if a data set of matrices is received, only the 1,1 data is considered. A data set specification like *S.21* is adequate, since this is a data set of complex numbers.

Input Arguments:

Data Sets:	Input 1
Output:	Single real or complex number
Automatic Invocation:	On Data Set Input Change

VBIC_ac_solver Given the 4 terminal voltages, solves for 2-port network parameters. VE and VS are assumed to be 0.

Input Arguments:

VC	(Collector Voltage)
VB	(Base Voltage)
FREQ	(Cut-off Frequency])
Output {FT|BETA|Y|H|Z|S}	Output code specifying current gain, or parameters. This code should be placed in the Output field.

Outputs:

The output depends on the code set in the Output field:

Code	Output
FT	Current gain cutoff frequency
BETA	Current gain
Y	The 2-port network y-parameters
H	The 2-port network h-parameters
Z	The 2-port network z-parameters
S	The 2-port network s-parameters

VBIC_avc Calculates avalanche collector voltage (AVC1) based on the model parameter PC.

$$AVC1 = \frac{a}{b(1-PC)}$$

Where

For an NPN, a = 7.05E05 cm^{-1} and b = 1.23E06 V/cm

For a PNP, a = 1.58E06 cm^{-1} and b = 2.04E06 V/cm

PC = b-c grading coefficient

Input Arguments:	None
Output:	Model parameter AVC1

VBIC_cbc Calculates the depletion capacitance versus bias.

Input Arguments:

VBC	Base-Collector Voltage
Output:	Depletion base-collector capacitance based on the VBIC formulation: SPICE model for AJC ≤ 0 and single-piece smooth model for AJC > 0.

VBIC_cbe Calculates the depletion capacitance versus bias.

Input Arguments:

VBE	Base-Emitter Voltage
Output:	Depletion base-emitter capacitance based on the VBIC formulation: SPICE model for AJC ≤ 0 and single-piece smooth model for AJC > 0.

VBIC_cj0 Calculates (extracts) the junction zero-bias capacitance.

Input Arguments:

VJ	Junction voltage
CJ	Capacitance
Output:	E/C/S Junction {E|C|S} for CJE, CJC, or CJCP
Output:	The zero-bias junction capacitance stored in CJE, CJC, or CJCP.

VBIC_clean_data This routine looks at each data point and scans ahead by the number of points specified by the input argument IN A ROW. If the data does not monotonically increase for the number of data points specified by IN A ROW, then zero is written to the output array. If the data does monotonically increase for the number of data points specified by IN A ROW, then from that data point onward, the INPUT DATA is written directly to the output (result) array.

Input Arguments:

INPUT DATA

IN A ROW

Output:	Either the INPUT DATA or zero values.

VBIC_csc Calculates the depletion capacitance versus bias.

Input Arguments:

VSC	(Substrate-Collector Voltage)
Output:	Depletion collector-substrate capacitance based on the VBIC formulation: SPICE model for AJC ≤ 0 and single-piece smooth model for AJC>0.

VBIC_dc_approx This function calculates Ic, Ib, beta, intrinsic and extrinsic base-emitter voltage, and base charge for a bipolar transistor, using the terminal voltages Ve, Vb, and Vc as inputs. Vs is assumed to be 0. The first parameter should be set to the output of interest, which defaults to Ic. This approximate solution does not take quasi-saturation effects into account.

Input Arguments:

VC	Collector Voltage
VB	Base Voltage
VE	Emitter Voltage
Output:IC|IB|BETA|VBEI|VBEX|QB	Set this field to the output of interest
Output:	The output depends on the setting of the Output field.

Code	Output
IC	Collector current
IB	Base current
BETA	Current gain

VBEI	Intrinsic base-emitter voltage
VBEX	Extrinsic base-emitter voltage
QB	Base charge

VBIC_dci_solver This function calculates Ic, Vb, Ie, Is, or beta for a bipolar transistor, using the terminal voltages Ve, Vc, and Vs and Ib as inputs. The first parameter should be set to the output of interest, which defaults to Ic.

Input Arguments:

VC	Collector Voltage
IB	Base Current
VE	Emitter Voltage
VS	Substrate Voltage
Output: IC|VB|IE|IS|BETA	
	Set this field to the output of interest.
Output:	The output depends on the code set in the Output field.
Code	Output
IC	Collector current
VB	Base voltage
IE	Emitter current
IS	Substrate current
BETA	Current gain

VBIC_dcv_solver This function calculates Ic, Ib, Ie, Is, or beta for a bipolar transistor, using the terminal voltages Ve, Vb, Vc, and Vs as inputs. The first parameter should be set to the output of interest, which defaults to Ic.

Input Arguments:

VC	Collector Voltage

VB	Base Voltage
VE	Emitter Voltage
VS	Substrate Voltage
Output: IC|IB|IE|IS|BETA	
	Set this field to the output of interest.
Output:	The output depends on the code set in the Output field:

Code	Output
IC	Collector current
VB	Base voltage
IE	Emitter current
IS	Substrate current
BETA	Current gain

VBIC_fg_currents Given the 4 terminal voltages, calculates parameters related to forward current.

Input Arguments:

Data Sets:	VC Collector Voltage VB Base Voltage VE Emitter Voltage VS Substrate Voltage IC Collector Current IB Base Current
Parameters:	The parameter indicates the region where the transform will limit its simulated output. VBIC_AUTO_RANGE must be set to 1.
IS|NF	Calculate over the region dominated by NF
IBEI|NEI	Calculate over the region dominated by NEI

IBEN|NEN	Calculate over the region dominated by NEN
IKF	Calculate over the region dominated by IKF
Output: {IB|B|IC|C|IE|E|IS|S}	
	Code to indicate which current to output.
Output:	A subset of the current where zeros replace any range where data was not extracted (based on the auto-ranging algorithm). The output depends on the code set in the Output field:
Code	Output
IB|B	Base current
IC|C	Collector current
IE|E	Emitter current
IS|S	Substrate current
Extracts:	Nothing

VBIC_ibci_nci Calculates the parameters IBCI and NCI.

Input Arguments:	
VB	Base Voltage
VC	Collector Voltage
IB	Base Current
Output:	NCI at each bias point (unaveraged).
Extracts:	IBCI, NCI

VBIC_ibei_nei Calculates the parameters IBEI and NEI.

Input Arguments:

VB	Base Voltage
VE	Emitter Voltage
IB	Base Current
Output:	NEI at each bias point (unaveraged).
Extracts:	IBEI, NEI

VBIC_ikf Calculates the parameter IKF.

Input Arguments:

VB	Base Voltage
VE	Emitter Voltage
IC	Collector Current
IB	Base Current
Output:	IKF at each bias point
Extracts:	IKF (maximum value in range, 0.1 indicates failed extraction).

VBIC_ikr Calculates the parameter IKR.

Input Arguments:

VB	Base Voltage
VC	Collector Voltage
IE	Emitter Current
IB	Base Current
Output:	Reverse beta versus bias.
Extracts:	IKR (maximum value in range, 0.1 indicates failed extraction).

VBIC_is_nf Calculates the parameters IS and NF.

Input Arguments:

VB	Base Voltage
VE	Emitter Voltage
IC	Collector Current
Output:	NF versus bias with 0's where out of auto-range.
Extracts:	IS, NF (average values in range).

VBIC_isp_nfp Calculates the parameters ISP and NFP.

Input Arguments:

VB	Base Voltage
VC	Collector Voltage
IS	Substrate Current
Output:	NFP versus bias with 0's where out of auto-range.
Extracts:	ISP, NFP (average values in range).

VBIC_nr Calculates the parameter NR.

Input Arguments:

VB	Base Voltage
VC	Collector Voltage
IE	Emitter Current
Output:	NR versus bias with 0's where out of auto-range.
Extracts:	NR (average value in range).

VBIC_qcdepl Calculates depletion charge or capacitance based on VBIC formulation using SPICE model for $A \leq 0$ and single-piece, smooth model for $A > 0$.

Input Arguments:

Junction V	Junction voltage
P Param	Built-in potential
M Param	Grading coefficient
F Param	Fwd bias depletion capacitance limit
A Param	Smoothing factor
Mode : {Q|C}	Charge or capacitance
Output:	Charge or capacitance versus bias.
Extracts:	Nothing

VBIC_rcx Calculates RCX.

Input Arguments:

VB	Base Voltage
VE	Emitter Voltage
IC	Collector Current
IS	Substrate Current
IB	Base Current
Output:	RCX versus bias with 0's where out of auto-range.
Extracts:	RCX (maximum value in auto-range, if failed, value of 60 set).

VBIC_rg_currents Given the 4 terminal voltages, calculates reverse currents.

Input Arguments:

VC	Collector Voltage
VB	Base Voltage
VE	Emitter Voltage

VS	Substrate Voltage
IE	Emitter Current
IB	Base Current
IS	Substrate Current
Parameters	The parameter indicates the region where the transform will limit its simulated output. VBIC_AUTO_RANGE must be set to 1.
IS|NR	Calculate over the region dominated by NR
IBCI|NCI	Calculate over the region dominated by NCI
IBCN|NCN	Calculate over the region dominated by NCN
IKR	Calculate over the region dominated by IKR
ISP|NFP	Calculate over the region dominated by NFP
IKP	Calculate over the region dominated by IKP
Output: {IB|B|IC|C|IE|E|IS|S}	
	Code to indicate which current to output.

Output: A subset of the current where zeros replace any range where data was not extracted (based on the auto-ranging algorithm).

The output depends on the code set in the Output field:

Code	Output
IB|B	Base current
IC|C	Collector current
IE|E	Emitter current
IS|S	Substrate current

Extracts:	Nothing.

VBIC_stoc This function calculates capacitance data from S-parameter data, allowing base-collector and base-emitter capacitance to be calculated from network analyzer measurements. The output of this function can be used in place of actual capacitance data to extract capacitance-related parameters.

Input Arguments:

FREQ data	Frequency
S data	S-parameter data (de-embedded)
Node (C/E/S)	Code to indicate type of extraction: E base-emitter capacitance C base-collector capacitance S substrate-collector capacitance
Output:	Capacitance versus frequency data
Extracts:	Nothing

VBIC_vef_ver Calculates the forward and reverse early voltages given the collector, base, and emitter voltages in the forward and reverse modes, as well as the collector current in the forward mode and the emitter current in the reverse mode. The algorithm is based on the method described in “SPICE Early Modeling” by C. McAndrew & L. Nagel, BCTM 94, p. 144.

Input Arguments:

Forward VC	Collector Voltage
Forward VB	Base Voltage
Forward VE	Emitter Voltage
Forward IC	Collector Current
Reverse VE	Emitter Voltage
Reverse VB	Base Voltage
Reverse VC	Collector Voltage

Reverse IE	Emitter Current
Forward IB	Base Current
Output:	VEF versus bias with 0's where out of auto-range.
Extracts:	VEF, VER (average values in auto-range).

Wait Switching matrix function. Used to pause for a specified number of seconds to accomplish *dry switching*. Refer to Chapter 2, "MOSFET Characterization," in the *IC-CAP Nonlinear Device Models, Volume 1* manual for more information.

Input Arguments:	
Reals or Integers:	Period [sec]
Output:	Single number with exit status
Automatic Invocation:	None

wirexfX A *wire* function. *Wire* functions permit optimization of time-domain measurements in the X and Y dimensions. Time-domain measurements involve effects specifically related to the Y axis (voltage or current level) or the X axis (when a pulse occurs).

Because X-axis data is typically the forced data set, it cannot normally be optimized. This makes it very difficult to optimize measured and simulated pulses that do not start with some amount of overlap in time. To solve this problem, the data can be transformed to create an independent X data set that can be optimized together with the Y data set. There are 2 ways of doing this.

- Generate the set of X values that would result if the Y values were evenly spaced. The *wirexfX* provides this data. The complementary *wirexfY* function provides the set of Y values that would result from evenly spaced X values, which is the default case.

- Generate the sets of X and Y values that would result if the X and Y axes are normalized and the curve is divided into segments of equal length. The *wirexfXY* and *wirexfYX* functions provide this data. This function calculates variably spaced X values for evenly spaced Y values.

  Input Arguments:

Data Sets:	X Data, Y Data
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

wirexfXY One of the *wire* functions that permit optimization of time domain measurements in the X and Y dimensions; for more details, refer to the *wirexfX* function. This function calculates the X data set produced when the X and Y axes are normalized and the curve is divided into segments of equal length. This function should be used in conjunction with *wirexfYX* during an optimization.

Input Arguments:

Data Sets:	X Data, Y Data
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

wirexfY One of the *wire* functions that permit optimization of time domain measurements in the X and Y dimensions; for more details, refer to the *wirexfX* function. This function calculates the Y data set when X values are evenly spaced. This function is supplied for completeness because Y data sets are normally collected in this manner.

Input Arguments:

Data Sets:	X Data, Y Data

Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

wirexfYX One of the *wire* functions that permit optimization of time domain measurements in the X and Y dimensions; for more details, refer to the *wirexfX* function. This function calculates the Y data set produced when the X and Y axes are normalized and the curve is divided into segments of equal length. This function should be used in conjunction with *wirexfXY* during an optimization.

Input Arguments:

Data Sets:	X Data, Y Data
Output:	Array of real numbers; size determined by inputs
Automatic Invocation:	On Data Set Input Change

9
Parameter Extraction Language

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IC-CAP's Parameter Extraction Language can be used to create new functions. This language is modeled on Rocky Mountain BASIC (*rmb*), the name adopted for *HP BASIC* or *Workstation BASIC* when HP introduced it on HP-UX. IC-CAP implements a subset that can aid in controlling the system and performing computations.

This chapter describes the syntax and operation of this interpreter. It is responsible for several IC-CAP system features:

- Numerical expressions in most editors in the system
- Transforms using the *Program2* or *Program* function
- Macros that a Model can use

Fundamental Concepts

The interpreter within IC-CAP can execute programs made up of statements that consist of keywords and expressions. Expressions are constructed from functions, identifiers, and operators. You enter these statements in the text editor that appears when you select *Program2* or *Program* as the function name in the Extract/Optimize folder, or when you open the Macros folder (refer to Chapter 11, "Creating and Running Macros," in the *IC-CAP User's Guide*). The same interpreter is used to evaluate the expressions entered in various tables providing a consistent syntax throughout the system. Strictly speaking, the expressions appearing in tables are not statements.

Keywords

Keywords are reserved by the Parameter Extraction Language. A keyword can be one of the reserved words required for a statement, such as *PRINT*.

It can also be a built-in function or a built-in constant. For keyword descriptions, refer to "Built-in Functions" on page 712 and "Built-In Constants" on page 744.

Keywords are entered in all uppercase or all lowercase, but not upper and lower case. For example, to call the built-in function *MAX*:

```
MAX(ic) or
max(ic)
```

Although the functions in IC-CAP's Function List can be invoked, those functions, such as *RMSerror*, are not language keywords. To be used in a Program, expression, or Macro, these functions must be spelled exactly as shown in the Function List.

Identifiers

Identifiers are Parameter Extraction Language variable names; they have the following properties:

- Identifiers can be of mixed case.

- An identifier can be any length.
- An identifier starts with an alphabetic character or an underscore character (_). It can include alphanumeric characters and underscore characters thereafter. Four notable exceptions to this are:
  - A subcircuit parameter, like *npn.BF*, is a legitimate identifier; a period (.) is allowed in this case.
  - A data set, like *npn/dc/fgummel/ic* is a legitimate identifier; a slash (/) is allowed in this case.
  - The notations ../ and ../.. are allowed to indicate relative paths in the currently executing macro or transform for dataset access.
  - In Programs and Macros, local variable names (identifiers) can end with a trailing dollar sign (*$*). Included for the convenience of BASIC programmers when using string variables, the only effect is that the program is easier to read. An example is: `Hi$="hello world"`

Numeric Precision

You can control numeric precision by setting the variables WORKING_PRECISION and/or PARAMETER_PRECISION or by using the PEL function val$().

- PARAMETER_PRECISION

  This variable controls the precision of parameters stored in the Model or DUT Parameters table, as well as the precision of parameters passed to a simulator.

- WORKING_PRECISION

  This variable controls the precision of numeric values when converted to text, but affects only those parts of a model for which the variable is defined. Depending on when and where the conversion occurs, precision can be actually lost or simply hidden. This conversion occurs in the following situations: any time the function val$() is called; the PRINT statement is used; a numeric value is

assigned to a variable in the IC-CAP Variable Table; a number is displayed to the screen (e.g., in an input/output/plot definition or tabular data) or saved to a file. (Because all variables in the IC-CAP Variable Table are text by definition, assigning a numeric value to such a variable will implicitly call the val$() function.)

Although the numbers are truncated for display purposes according to the WORKING_PRECISION variable, IC-CAP uses the untruncated numbers for calculations until the file is saved. After the truncated numbers are saved in a file then reread, the truncated numbers are used in calculations. For example, if you type 1.23456 into an input field, 1.235 is displayed. However, 1.23456 is used for calculation. After the file is saved and reread, 1.235 is not only displayed but also used for calculations.

When you change the WORKING_PRECISION variable, the change is only apparent with subsequently edited or redisplayed fields.

The value of the WORKING_PRECISION variable applies to the precision of the Start/Stop/Stepsize fields of inputs, though not all instrumentation can support such resolution. Using higher precision involving these fields should be done with caution.

The range of values is 6 through 17. The default is 6.

Controlling precision through val$() calls

The function val$() has an optional second argument that can be used to control numeric precision. For example, the statement *y=val$(x,12)* will convert the number x to a string using up to 12 significant digits if required. Use this form of val$() when the current value of WORKING_PRECISION is acceptable for most of the work at hand, but greater control is required for isolated instances. In those instances, the second argument of val$() can be used to override the current working precision.

The examples that follow show how the output varies based on whether or not the WORKING_PRECISION variable is defined, and how the WORKING_PRECISION variable, when defined, is overridden by using val$().

NOTE When doing comparisons on real numbers, you may see unexpected results (PEL printouts are rounded, although full precision is used internally). Using the new WORKING_PRECISION variable or the val$(xxx,y) function, you can verify the actual value.

For example, consider the following PEL clause:

```
x=0.39999999999
IF x < 0.4 THEN
     PRINT x;“is less than 0.4”
END IF
```

Since x=0.39999999999, the IF clause will be entered but it will print *0.4 is less than 0.4*. To verify the actual value, change the x in the print statement to val$(x,15) . The output will then show *0.39999999999 is less than 0.4*.

```
PRINT val$(x,15);“is less than 0.4
```

Example, Scenario 1

This scenario shows the usefulness of the new argument in the val$() function.

Conditions: No WORKING_PRECISION variable is declared within current scope; var1, and var2 are variables in the Variable table within the current scope.

PEL

```
x=0.1234567890123 ! implicit val$() used behind the scenes uses
var1=x            ! default working precision (6 digits)
var2=val$(x,9)    ! explicit val$() specifying 9 digits of precision
y=0+var1          ! implicit val() used on var1 to make numeric again
z=0+var2          ! implicit val() used on var1 to make numeric again
print “Default precision x=”,x      ! default working precision used
print “Default precision y=”,y      ! default working precision used
print “Default precision z=”,z      ! default working precision used
print “var1=”,var1                  ! no conversion--var1 already text
print “var2=”,var2                  ! no conversion--var2 already text
print “High precision x=”,val$(x,9) ! explicit working precision
print “High precision y=”,val$(y,9) ! explicit working precision
print “High precision z=”,val$(z,9) ! explicit working precision
```

Output

```
Default precision x=  0.1235
Default precision y=  0.1235
Default precision z=  0.1235
var1=                 0.1235
var2=                 0.123456789
High precision x=     0.123456789
High precision y=     0.1235
High precision z=     0.123456789
```

Notice that y lost precision because var1 lost precision, however it is clear from the High precision lines that more information is available for x and z even though printing at the default precision did not reveal it.

Example, Scenario 2

This Scenario uses the same code as Scenario 1, except that the default working precision has been increased via the WORKING_PRECISION variable.

Conditions: WORKING_PRECISION variable in the current scope is set to 12; var1 and var2 are variables in the Variable Table within the current scope.

PEL

```
x=0.1234567890123   ! implicit val$() used behind the scenes uses
var1=x              ! current working precision (12 digits)
var2=val$(x,9)      ! explicit val$() specifying 9 digits of precision
y=0+var1            ! implicit val() used on var1 to make numeric again
z=0+var2            ! implicit val() used on var1 to make numeric again

print “Default precision x=”,x    ! current working precision used
print “Default precision y=”,y    ! current working precision used
print “Default precision z=”,z    ! current working precision used
print “var1=”,var1                ! no conversion--var1 already text
print “var2=”,var2                ! no conversion--var2 already text
print “High precision x=”,val$(x,9) ! explicit working precision
print “High precision y=”,val$(y,9) ! explicit working precision
print “High precision z=”,val$(z,9) ! explicit working precision
```

Output

```
Default precision x=  0.123456789012
Default precision y=  0.123456789012
Default precision z=  0.123456789
var1=                 0.123456789012
var2=                 0.123456789
High precision x=     0.123456789
High precision y=     0.123456789
High precision z=     0.123456789
```

In this case, notice that the overriding val$() assignments actually lower the default precision since the default has been set to 12 digits via the WORKING_PRECISION variable.

Statements

This section describes how to write statements that make up Programs and Macros. The information in this section is not required to use expressions in the editor tables within IC-CAP.

Rules for Constructing Statements

As in BASIC, statements are generally contained in a single line of input. On the other hand, a quoted string can be as many lines long as needed and can contain CR-LFs (carriage return-line feeds).

Statements can be arbitrarily complex, and can use parentheses and white space to clarify precedence and improve readability.

Keywords must be all uppercase or all lowercase characters. Calls to functions in IC-CAP's Function List must be spelled exactly as they are in the Function List.

Use an exclamation mark (!) to comment out a line or any part of a line.

Available Statements and Commands

The following statements are taken from HP BASIC. They are sensitive to the use of CR-LF, and must be written as shown. For example, the ELSE keyword should be followed by nothing on the same line, although a comment (starting with !) could follow it. In this section, the abbreviation *expr* denotes an expression. Expressions are described in "Expressions" on page 745. The abbreviation *boolean_expr* denotes a boolean expression, generally 0 or 1 (1, as well as any non-zero value, is considered TRUE). For more information, refer to "Boolean Expressions" on page 747.

IF THEN with a single statement

```
IF boolean_expr THEN statement
```

IF THEN with multiple statements

```
IF boolean_expr THEN
statement1
.
.
.
statementN
END IF
```

IF THEN ELSE statement

```
IF boolean_expr THEN
statement1
.
.
.
statementN
ELSE
statement1
.
.
.
statementN
END IF
```

WHILE statement

```
WHILE boolean_expr
statement1
.
.
.
statementN
END WHILE
```

GET_DATASET statement

```
GET_DATASET prompt_string, variable_name
GET_DATASET prompt_string, default_string, variable_name
```

GET_DATASET is currently only supported by the Program2 function. An error occurs if used with a Program function or Macro. GET_DATASET can redirect a Program2 dataset or array parameter argument into a named variable. The *prompt_string* and optional *default_string* parameters are currently unused and ignored. The *variable_name* argument is a variable that receives the redirected Program2 parameter argument. The named variable can be a variable local to the Program2 function. After the GET_DATASET statement finishes, it returns a dataset to the named variable. Currently the named variable can not represent a global variable or variable from an IC-CAP variable table.

Example Program2 function transform using GET_DATASET:

```
sub_prog
{
   PRINT "enter sub_prog"

   ! re-direct a dataset parameter argument passed into
this
   ! function into local variable loc_x
   GET_DATASET "", loc_x

   PRINT "loc_x == "
   PRINT loc_x

   PRINT "leave sub_prog"
   RETURN
}
```

Example:

```
! create a small dataset x
COMPLEX x[5]
i = 0
WHILE i < sizeof(x)
   x[i] = i+2 + j*(i+1)
   i=i+1
ENDWHILE

! pass a small dataset x to the Program2 function sub_prog
iccap_func("sub_prog", "Execute", x)
```

Output:

```
enter sub_prog
loc_x ==
Point   Index   R:measured     I:measured
   0   (1,1)  2.000000E+000  1.000000E+000
   1   (1,1)  3.000000E+000  2.000000E+000
   2   (1,1)  4.000000E+000  3.000000E+000
   3   (1,1)  5.000000E+000  4.000000E+000
   4   (1,1)  6.000000E+000  5.000000E+000
Point   Index   R:simulated    I:simulated
   0   (1,1)  2.000000E+000  1.000000E+000
   1   (1,1)  3.000000E+000  2.000000E+000
   2   (1,1)  4.000000E+000  3.000000E+000
   3   (1,1)  5.000000E+000  4.000000E+000
   4   (1,1)  6.000000E+000  5.000000E+000

leave sub_prog
```

GET_INT statement

```
GET_INT prompt_string, variable_name
GET_INT prompt_string, default_string, variable_name
```

Uses a dialog box to request an integer input from the user, prompting with *prompt_string*, which should be a quoted string, an identifier, or an expression treated as an integer. Where applicable, *default_string* provides the user with a default answer, enabling the user to simply select *OK* and avoid typing any data. The *prompt_string* can be any valid

string expression. The *default_string* can be any valid string expression representing an integer. The *variable_name* argument is a variable that receives the user's response. The variable can be an IC-CAP system variable, or a variable local to Program, Program2, or Macro. After the GET_INT statement finishes, it returns an integer value to the named variable. If the named variable is a global variable, the integer value will be stored in the variable table.

The GET_INT dialog box contains 2 buttons: *CANCEL* and *OK*. Choose *CANCEL* to terminate Program, Program2, or Macro immediately.

If GET_INT is used in a Program or Macro to pass parameters, all GET_INT statements should be located immediately at the start of the Program or Macro along with any other GET_INT, GET_REAL, GET_STRING or LINPUT statements. Once any other ICCAP_FUNC statement is invoked, the list of arguments is reset, thereby removing all the extra arguments from the calling ICCAP_FUNC statement. Program2 does not have this limitation.

If GET_INT is used in a Program or Macro to pass parameters, the GET_INT statement searches the passed parameter list until it finds a valid passed integer parameter argument. In the Program2 function, the GET_INT statement will only try to evaluate the next available passed function parameter as an integer value, and will error out if the next passed function parameter can not be evaluated as an integer value.

GET_REAL statement

```
GET_REAL prompt_string, variable_name
GET_REAL prompt_string, default_string, variable_name
```

Uses a dialog box to request a real input from the user, prompting with *prompt_string*, which should be a quoted string, an identifier, or an expression treated as a real value. Where applicable, *default_string* provides the user with a default answer, enabling the user to simply select *OK* and avoid typing any data. The *prompt_string* can be any valid string expression. The *default_string* can be any valid string expression representing a real value. The *variable_name* argument is a variable that receives the user's response. The

variable can be an IC-CAP system variable, or a variable local to Program, Program2, or Macro. After the GET_REAL statement finishes, it returns a real value to the named variable. If the named variable is a global variable, the string value will be stored in the variable table.

The GET_REAL dialog box contains 2 buttons: *CANCEL* and *OK*. Choose *CANCEL* to terminate Program, Program2, or Macro immediately.

If GET_REAL is used in a Program or Macro to pass parameters, all GET_REAL statements should be located immediately at the start of the Program or Macro along with any other GET_INT, GET_REAL, GET_STRING or LINPUT statements. Once any other ICCAP_FUNC statement is invoked, the list of arguments is reset, thereby removing all the extra arguments from the calling ICCAP_FUNC statement. Program2 does not have this limitation.

If GET_REAL is used in a Program or Macro to pass parameters, the GET_REAL statement searches the passed parameter list until it finds a valid passed real parameter argument. In the Program2 function, the GET_REAL statement will only try to evaluate the next available passed function parameter as a real value, and will error out if the next passed function parameter can not be evaluated as a real value.

GET_STRING statement:

See “LINPUT or GET_STRING statement” on page 697. GET_STRING is simply an alternate name for the LINPUT command. The new name is consistent with GET_INT, GET_REAL, and GET_DATASET.

GLOBAL_VAR statement

```
GLOBAL_VAR <variable_name>
```

Declares a variable as a global variable in a program. This statement is most useful for the Program2 function, because the Program2 function treats all variables as local variables unless those variables are first explicitly declared as global variables using the GLOBAL_VAR statement. In the Program

function, all variables can be resolved globally or locally without needing to explicitly specify which variables are global using the GLOBAL_VAR statement.

The *variable_name* should refer to an IC-CAP variable in a variable table. Before using a variable from a variable table in Program2, you should declare the variable as global with GLOBAL_VAR. An error will occur if an IC-CAP variable could not be found.

```
GLOBAL_VAR varX
y=varX
RETURN y
```

ICCAP_FIND_CHILDREN statement

```
ICCAP_FIND_CHILDREN "/","Model",loadedModels
```

Sets a variable to be the list of names of a particular child type of an IC-CAP object. This turns the variable *loadedModels* from a variable table into an ICCAP_ARRAY containing elements that are the names of the currently loaded models. Use the *sizef()* command to determine the size of the array.

Refer to the following table for valid names for the second argument given the type of the first argument.

First Argument References	Second Argument may be
/	Model
any GUI Item Table or any GUI Item	GUI Item
any model	DUT
any DUT	Setup
Any Setup	Input, Output, Transform, or Plot

NOTE You should use *sizeof()* instead of *size()* because if no objects of the requested type are found, a null string ("") is returned instead of an ICCAP_ARRAY[0]. Since *size()* returns 1 for a null string, you would first test the result to make sure it is not a null string before using the *size()* command to determine the number of entries. The *sizeof()* function returns 0 for a variable that is not an ICCAP_ARRAY[].

ICCAP_FUNC statement

```
ICCAP_FUNC (object_name, menu_function_name, dialog_answer1, ...)
```

Used primarily in macros for automating the operation of IC-CAP.

NOTE The ICCAP_FUNC statement replaced the MENU_FUNC statement in release 5.0. For backward compatibility, macros containing the MENU_FUNC statement will still work, but new macros should be written using the ICCAP_FUNC statement.

For an example on using the ICCAP_FUNC statement, refer to Chapter 11, “Creating and Running Macros,” in the *IC-CAP User’s Guide*.

LINPUT or GET_STRING statement

```
LINPUT prompt_string, variable_name
LINPUT prompt_string, default_string, variable_name
GET_STRING prompt_string, variable_name
GET_STRING prompt_string, default_string, variable_name
```

Uses a dialog box to request a string input from the user, prompting with *prompt_string*, which should be a quoted string, an identifier, or an expression treated as a string. Where applicable, *default_string* provides the user with a default answer, enabling the user to simply select *OK* and avoid typing any data. Like *prompt_string*, the *default_string* can be any valid string expression. The *variable_name* argument is a variable that receives the user’s response. The variable can be an IC-CAP system variable, or a variable local to the Program, Program2, or Macro. After the LINPUT or GET_STRING statement finishes, it returns a string to the named variable. This will either be the null string (""), or a string defining the text that would be typed in the LINPUT or GET_STRING dialog box. If the named variable is a global variable, the string value will be stored in the variable table. To interpret the results as a number, you must use *val()*.

The LINPUT or GET_STRING dialog box contains 2 buttons: *CANCEL* and *OK*. Choose *CANCEL* to terminate Program, Program2, or Macro immediately.

If LINPUT or GET_STRING is used in a Program or Macro to pass parameters, all LINPUT or GET_STRING statements should be located immediately at the start of the Program or Macro along with any other GET_INT, GET_REAL, GET_STRING or LINPUT statements. Once any other ICCAP_FUNC statement is invoked, the list of arguments is reset, thereby removing all the extra arguments from the calling ICCAP_FUNC statement. Program2 does not have this limitation.

PRINT statement

```
PRINT expr
```

Writes an ASCII printout of the given expression to the Status window or location specified by a preceding PRINTER IS statement. As in HP BASIC, several arguments can be used, and these can be separated by a semicolon (;), comma (,), or a period (.). The semicolon separator results in no spacing between printed arguments, while the comma separator results in a tab character. When printing multiple arguments, the ampersand (&) operator and the VAL$ function may be useful. Refer to “Built-in Functions” on page 712 and “Expressions” on page 745.

PRINTER IS statement

```
PRINTER IS <string>
```

Specifies where subsequent PRINT statements write. String specifies a path and filename for subsequent PRINT statements. A special token *CRT* specifies that subsequent PRINT statements write to the Status window. For example:

```
PRINTER IS “/tmp/tmpfile”
PRINT “This text is going to tmpfile”
PRINTER IS CRT
PRINT "This text is going to the status window”
```

RETURN statement

```
RETURN [expr]
```

Copies a data set expression into the local storage of the Transform, making the data available to Plots or other Transforms that may reference it. In both Program and Program2, it can be used to store data by including the

optional argument. In a Macro, no argument can be present. In both cases, Program, Program2, or Macro terminates after this statement is executed. For example:

```
Id = IS * exp(vd / NF / vt)
RETURN Id
```

RETURN_VALUE statement

```
RETURN_VALUE expr
```

Interprets *expr* as a single real value. If *expr* is a dataset, the first value will be returned. If *expr* is a variable, it will interpret the value as a real value. If the variable is an ICCAP_ARRAY, it will interpret the string as a number, returning the dimension of the ICCAP_ARRAY, not the first value of the array. RETURN_VALUE copies a real value from an expression into the local storage of the Transform, making the data available to Plots or other Transforms that may reference it. Both Program and Program2 terminates after this statement is executed. Use RETURN_VALUE when only a single return value is required. This will avoid IC-CAP increasing the size of the return value to the size of the setup. The RETURN_VALUE statement's returned dataset will be size 1, whereas the RETURN statement's return dataset size will be determined by the size of the setup. RETURN_VALUE is unsupported with Macros.

For example:

```
Id = 23.44
RETURN_VALUE Id
```

TUNER statement

```
TUNER pname, min, initValue, max, linLogScale, cbStyle,
cbName
```

where:

pname: is a string (or variable array, refer to the section “Using Variable arrays”) containing the name of the variable or parameter you want automatically adjusted each time the tuner is adjusted.

min: is a number (or variable array, refer to the section “Using Variable arrays”) that specifies the minimum end of the tuner scale.

initValue: initValue is a number (or variable array, refer to the section “Using Variable arrays”) that specifies the initial position of the slider.

max: is a number (or variable array, refer to the section “Using Variable arrays”) that specifies the maximum end of the tuner scale

linLogScale: is a number (or variable array, refer to the section “Using Variable arrays”) that specifies whether the tuner will have a log scale or not.

cbStyle: is a number (1 or 0) that specifies whether or not the callback is called continuously as the slider moves (while the user has the mouse button pressed) or only when the slider motion is complete (when the user releases the mouse button). 1 Specifies continuous callbacks; 0 specifies endpoint callbacks.

cbName: is a string that specifies a Macro or Transform in the same manner you would refer to a macro or transform using a ICCAP_FUNC statement. This Function will be called as indicated by *cbStyle*. For example, you may have a macro named *cb* in model *m1* and you could specify this macro absolutely with “*/m1/cb*” or relatively by “*cb*” from any macro within *m1*.

SLIDER statement

```
SLIDER pname, min, initValue, max, OKFlag, retVal
```

where:

pname:	is a string (or variable array, refer to the section “Using Variable arrays”) containing the name of the variable or parameter you want automatically adjusted each time the tuner is adjusted.
min:	is a number (or variable array, refer to the section “Using Variable arrays”) that specifies the minimum end of the tuner scale.
initValue:	initValue is a number (or variable array, refer to the section “Using Variable arrays”) that specifies the initial position of the slider.
max:	is a number (or variable array, refer to the section “Using Variable arrays”) that specifies the maximum end of the tuner scale
okFlag	is an expression. 0 means return as soon as the slider is adjusted; nonzero means return only when user clicks OK.
retVal	If more than one slider is specified, using arrays, retVal returns the index of the modified slider and the new value is automatically updated to the initValue array. If only one slider is specified via means other than variable arrays, retVal returns the new value of the slider.

Using Variable Arrays

To specify multiple parameters or variables for tuning, you can use variable arrays. The arguments *pname*, *min*, *initValue*, and *max* must all be variable arrays of the same dimension. (A variable array is defined by setting the value of any variable in a variable table to ICCAP_ARRAY[dim] where dim is the dimension of the array.) For example, if *names*, *mins*, *maxs*, and *currs* were all variable arrays of dimension 4, and *names* was an array of *param names* and *mins* was an array of *min values*, etc, the statement

```
TUNER names,mins,currs,maxs,0,1,"mycallback"
```

would invoke a TUNER with 4 sliders on it, one for each parameter in the names array.

NOTE Clicking OK on the tuner returns control to the Macro; clicking CANCEL on the tuner aborts the macro currently running.

You can set and access *n*-dimensional variable arrays. If you set the arrays

```
a=ICCAP_ARRAY[2]
a[0]=ICCAP_ARRAY[2]
```

you can then access and set `a[0][1]` in PEL.

UPDATE_EXPLICIT,

UPDATE_MANUAL,

UPDATE_AUTO,

UPDATE_EXTRACT, and

UPDATE_OPTIMIZE statements

Tell IC-CAP when to automatically run a Program. These statements do not affect the Program, as can be seen in the following examples:

```
UPDATE_EXPLICIT   !suppress all auto-execution of the
                  !transform
UPDATE_MANUAL     !suppress all auto-execution of the
                  !transform except during an optimization
UPDATE_AUTO       !auto-execute the transform if a data set
                  !input changes
UPDATE_OPTIMIZE   !auto-execute upon selection of the
                   !Optimize menu function
UPDATE_EXTRACT    !auto-execute upon selection of the
                   !Extract menu function
```

NOTE UPDATE_MANUAL will auto-execute a transform during an optimization only if it is a dependency on the simulated target of the optimization.

Use only 1 statement per Program and place the statement first in the Program. They have no effect in a macro because macros are never automatically executed by IC-CAP. For more information about the automatic execution of Programs, refer to "Automatic Transform Execution" in the *User's Guide*.

COMPLEX statement

```
COMPLEX <array_name>.<type>.<matrix_dimensions>[size_expr]
```

Declares a temporary variable as an array. The individual points of such an array can be manipulated, after which the *RETURN* statement can be used to save the contents. The *array_name* and *size_expr* arguments must be provided. The type specifier and *matrix_dimensions* specifier are optional. The *matrix_dimensions* can be either literal or an expression in ( ) up to 9999. Only a square matrix is currently supported.

The following examples demonstrate the various forms that the *COMPLEX* statement can take. For information on understanding the use of the M, S, and B specifiers, refer to "Measured, Simulated, and Common Data" in the *IC-CAP User's Guide*. (These specifiers identify whether space is allocated for measured, simulated, both measured and simulated, or for data to be considered *common*.) "Data Types" on page 708 explains the M, S, and B specifiers. The matrix dimensions specifier should be equal to 22 for 2-port data. For DC data sets it is simplest to omit it; this results in a default value of 11 (1x1 data) suitable for DC, CV, TDR and other non-2-port data sets.

```
COMPLEX tmp_array[30+5] ! Common data; 35 complex points;
                        !indexed 0 to 34
COMPLEX tmp_array.M[35] ! Measured data
COMPLEX tmp_array.S[35] ! Simulated data
COMPLEX tmp_array.B[35] ! Both measured and simulated data
                        ! is allocated
COMPLEX t_arr.22[30+5]  ! Common data; 35 2x2 (i.e. 2-port)
                        !points
COMPLEX t_arr.M.22[35] ! Measured data; 35 2x2 points
COMPLEX t_arr.S.22[35] ! Simulated data; 35 2x2 points
COMPLEX t_arr.B.22[35] ! Both measured and simulated data is
                       ! allocated
COMPLEX t_arr.B.1212[35] ! 12x12 matrix
COMPLEX t_arr.B.(r*10+c)[35] ! r, c up to 9x9
COMPLEX t_arr.B.(r*100+c)[35] ! r, c up to 99x99
```

After an array is declared using *COMPLEX*, all elements have a value of 0. Refer to "Assignment" on page 704 for a description of how to modify elements within the array. Examples of data set access are provided in "Data Types" on page 708. Those examples also apply to accessing the temporary arrays declared by *COMPLEX* and the points within them.

The *COMPLEX* statement is not always necessary when working with arrays. In many cases, assignment and other operations can be done implicitly on an array-wide basis. For example, the following statements produce the average of two 2-port S-parameter data sets:

```
x = (S1+S2) / 2
RETURN x
! or, simply,
RETURN (S1+S2) / 2
```

When individual points in the array require differing and non-trivial manipulations (thus making it necessary to assign to them on a point-wise basis), use the *COMPLEX* statement. Typical applications are filtering noise from data or producing a new data set that contains only a subset of another data set.

Assignment

Assignment is an important statement for complicated computations that require temporary variables or perform extractions. An assignment statement consists of a simple identifier on the left, an = sign, and any allowed expression to the right. It is possible to declare temporary arrays (using *COMPLEX*) and to assign values to individual points within these arrays.

NOTE A single equal sign (=) is used to indicate *assignment;* a double equal sign (==) is used to test for equality. HP BASIC uses = for both.

The valid forms for assignment are as follows:

```
tempvar = <any expression>
<Model parameter> = <REAL expression>
<DUT parameter> = <REAL expression>
```

```
<IC-CAP system variable> = <REAL expression>
<tmp_array>.<type>.<row_and_column>[index_expr] = <REAL or
COMPLEX expression>
```

In the last case, some fields are optional. The following examples show every legitimate case and demonstrate all valid forms of assignment.

BF = ic[0]//ib[0]	Assigns the bjt Model parameter *BF* to the ratio of 2 points (ic[0] and ib[0]).
AREA = 1.2	Assigns (in a bjt Model) a value to the DUT parameter *AREA*.
npn2.BF = 100	Assigns a value to the Model parameter *npn2.BF*, if the current Model possesses such a parameter. Failing that, it assigns a value to a BF parameter in another Model named *npn2*.
npn2/dc.AREA = 100	Assigns a value to the DUT parameter *AREA*, within the DC DUT of a Model named *npn2*.
TNOM = 25	TNOM is generally defined as an IC-CAP system variable. Here it is assigned a value of *25*.
x = 4	Declares x a temporary variable and assigns an integer. Recommended for loop counters. The maximum integer that you can set is 2147483647 (MAXINT). If you attempt to assign an integer in excess of MAXINT, unreported overflow errors will occur and the actual integer assigned will not be the value you attempted to assign. If you wish to use numbers larger than MAXINT, specify using a .0 at the end of the number (see x = 4.0) or use engineering notation.

x = 4.0	Declares *x* a temporary variable and assigns a double precision floating point number. Not recommended for loop counters due to roundoff errors.
x = ic//ib	Declares *x* a temporary variable and assigns it to the ratio of the 2 data sets (ic and ib). Refer to "Expressions" on page 745 for an explanation of the double slash (//).
x = S.21	Declares *x* a temporary variable and assigns to it all the 21 (forward transmission) data within a 2-port data set named *S*.
x = S.M.21	Declares *x* a temporary variable and assigns to it all the measured 21 (forward transmission) data within a 2-port data set named *S*.
x = ic or x = ic.m or x = ic.s	Declares *x* a temporary variable and assigns to it the data within an Output named *ic*. If *ic* only has measured data, only measured data is assigned to *x*. If *ic* only has simulated data, only simulated data is assigned to *x*. If *ic* has both measured and simulated data, both are assigned to *x*. If *x* is not the correct size for the requested data, *x* resizes to accommodate the data on the right side.

x.m = ic or x.m = ic.s or x.m = ic.m	If *x* has never been assigned or was assigned some value other than a temporary dataset, adding *.m* to left side has no effect. See x=ic, x=ic.s, x=ic.m. If *x* was previously defined as a temporary dataset, assigns to its measured array the data within an output named *ic*. If *ic* contains just simulated data or if the right side is *ic.s*, *x* receives just the simulated data in its measured array. If *ic* contains common or measured data or if the right side is *ic.m*, *x* receives that data in its measured array. If *x* contains preexisting simulated data, that simulated data is not changed. If *x* is not the correct size for the requested data, an error occurs.
x.s = ic or x.s = ic.s or x.s = ic.m	If *x* has never been assigned or was assigned some value other than a temporary dataset, adding *.s* to left side has no effect. See x=ic, x=ic.s, x=ic.m. If *x* was previously defined as a temporary dataset, assigns to its simulated array the data within an output named *ic*. If *ic* contains just simulated data or if the right side is *ic.s*, *x* receives just the simulated data in its simulated array. If *ic* contains common or measured data or if the right side is *ic.m*, *x* receives that data in its simulated array. If *x* contains preexisting measured data, that measured data is not changed. If *x* is not the correct size for the requested data, an error occurs.

The following statements demonstrate assignment to points in temporary arrays. They require prior use of the *COMPLEX* statement to declare the temporary array appearing to the left of the equal sign (=). An array index *i* is assumed in each case to be an integer or integer expression. It should have a value between 0 and *size-1*, where *size* was established in a *COMPLEX* statement.

```
tmp_array.M[i] = 2+2 ! Measured data point assigned value of
                     ! 4
tmp_array.S[i] = 2+2 ! Simulated data point assigned value
                     ! of 4
tmp_array.B[i] = 2+2 ! Measured and simulated data points
                     ! are BOTH assigned
tmp_array_x[i] = 2+2 ! Common or measured data point
                     ! assigned value of 4
tmparr.M.21[i] = 2+j5 ! Measured '21' data point receives
                      ! complex
tmparr.S.21[i] = 7+20 ! Simulated '21' data point receives
                      ! real
tmparr.B.21[i] = 2+j5 ! Measured and simulated '21' data
                      ! points are BOTH assigned
tmparr_x.21[i] = 2+j5 ! Common or measured '21' data point
                      ! receives complex
```

The following assignment statements are not valid:

```
COMPLEX x.m[size(beta.m)]
x.m = beta.m ! left-side expression must be simple
             ! identifier, or individual point
S = S + S
```

where S is an existing IC-CAP data set. You cannot overwrite an existing data set in this manner. (However, you could establish an IC-CAP data set with identical data using *RETURN S+S* .)

```
tmp_array[i] = S[i] ! not valid if S[i] is non-scalar (for
                    ! example, 2-port data)
```

Data Types

This section describes the primitive data types supported in expressions, Programs, and Macros. These types of data represent the simplest possible expressions.

Because IC-CAP automatically assigns data types, it is not necessary to declare a data type for a variable. Thus, to declare and initialize a temporary variable in a *Program* Transform or Macro, assign a value to it. For example, entering *tempvarx* = *S.m.21[3]* automatically makes *tempvarx* a complex entity (*S* is assumed to be 2-port data). The variable *tempvarx* is known

only to the Transform program being defined and is discarded when the program finishes. IC-CAP recognizes and operates on the following data types:

real (or double) For example:
`2.0, 2e-6, and 2.0k.`

complex Engineering and scientific notation are accepted in any mix. For example:
`2+j2, 2+j*2, and 2.05meg-j1.0e6.`

pure imaginary j*2, j2, j, and j*1meg.

matrix The expression S.M[0] is a matrix example if S is 2-port data.

Model and DUT Parameters These are scalar real numbers. When IC-CAP encounters such an identifier (BF for example), it searches for a match in the following order until one is found:

1. DUT level parameter
2. Model level parameter
3. Setup level parameter
4. DUT level variable
5. Model level variable
6. System level variable
7. Datasets

Model parameters can be used in, or assigned to, expressions.

For example:

```
BF = 100
x = 2 * BF
npn1.BF = 100 !BF in another Model
npn1/dc.AREA=1 !AREA in another DUT
```

IC-CAP variables Refer to *Model Parameters* for a description of how IC-CAP resolves the meaning of symbol names. Like *Model Parameters*, system variables can be used in, or assigned to, expressions. They have one enhanced capability not shared by the parameters—a string can be assigned to them. For example,

```
EXTR_MODEL="opamp"
```

Do not attempt to enter an expression when editing an IC-CAP system variable table. This will not be evaluated when you later reference the variable. If the system variable is used in a numeric expression, it is safest to enter only a single number in the system variable table. To obtain the text contents of a system variable, use the following:

```
VAL$(EXTR_MODEL)
```

where EXTR_MODEL is a system variable.

data set Arrays of matrices of complex numbers. In the most complex case (2-port S-parameter measured and simulated data), data sets hold an array of measured matrices and an array of simulated matrices. (Refer to "Measured, Simulated, and Common Data" in the *IC-CAP User's Guide*.) IC-CAP entities considered to be data sets are Inputs, Outputs, and Transforms. The syntax for accessing all or part of a data set is described in the following paragraphs. Temporary arrays, such as those declared by the *COMPLEX* statement, can also be accessed using the syntax in the examples.

In the following examples of data set access, *S* denotes an existing data set of 2-port data; *IC* denotes an existing DC data set. Both data sets are type *B* (*both)*—they contain measured and simulated data.

NOTE These examples are valid for *reading* data in a temporary array in a Program or Macro, and for *reading* data in an IC-CAP data set. However, choices are more limited when assigning to *(writing to)* temporary arrays; also, no assignment can be done directly into IC-CAP data sets (outside of the *RETURN* statement). For details regarding assignment statement, refer to "Assignment" on page 704.

IC.M	Produces a data set containing only measured data.
IC.S	Produces a data set containing only simulated data. *M* (measured), *S* (simulated), and *B*(both) act as keywords and can be specified in either uppercase or lowercase.

IC.B or IC Produces a data set containing both measured and simulated data.

S[2] or S.M[2] Produces a matrix of measured data. It is the third matrix in S.M, the first being S[0]. An expression can be substituted for *2*. In the first case, the system selects measured data by default. Since 2 selects the third matrix, 0 would select the first matrix. This is consistent with HP BASIC, in which *OPTION BASE 0* is the default when accessing array elements. The last matrix in S.M can be accessed with the built-in function *SIZE*: S[size(S)-1]. Results are undefined if you attempt to use indices that are negative or are beyond the end of the data set.

IC[0] or IC.M[0] Produces a real number that is the first point in IC's measured data. An expression can be substituted for 0. Note: Omitting the *.M* extension (*IC[0]*) defaults to measured data only, *NOT* both measured and simulated data.

S.s[2] Produces a matrix of simulated data that is the third point (the first is S.s[0]). An expression can be substituted for *2*.

*S.21 S.0201 S.9181 S.(row*10+column) S.(row*100+column)*

Produces a measured and simulated data set with complex data. The term *.21* specifies that the data at row 2, column 1 is to be extracted from data set *S* (this would be the data corresponding to the forward transfer coefficient). The term *.21* can be expressed either literally or by an expression in parentheses ( ) up to 9999. (Note that S.21 and S.0201 are equivalent.) For data sets with more than 9 rows or columns, use the 4-digit row-column specification, for example, S.9902 (row 99, column 2).

S.21[0]	Produces a complex number. *M* (measured) is assumed by default. The result is the data for row 2, column 1 of S's first measured data matrix. An expression can be substituted for *0*.
S.S.21[2]	Produces the same result as above, but for simulated rather than measured data.

IC-CAP also has some limited string manipulation capabilities. The following are examples of the string type (note the 2 alternatives for including quotation marks in a string):

```
"hello world"
"IC-CAP says 'hello world' "
'IC-CAP says "hello world" '
```

The following is an example of a string used in a statement:

```
PRINT "hello world"
```

Assign to x as follows:

```
x = "hello"
```

and x will be of type string.

Built-in Functions

The functions described in this section are built into the Parameter Extraction Language. They can be entered in all uppercase or all lowercase, as in HP BASIC.

Some are duplicated in the IC-CAP Function List, like *log*. Some functions were built in for efficiency with scalar data (the Function List has functions designed to operate best on data sets). Other built-in functions are for programming convenience, such as *size* and *system$*.

NOTE A function applied to a data set, unless otherwise noted, generates a new data set in which the specified function has been applied to every point. However, the functions *max, min,* and *size* each return single numbers only.

abs

Absolute value of a single real number or magnitude of a complex number.

array_copy(x,yout)

Returns 0 if the ICCAP_ARRAY x is copied successfully to the ICCAP_ARRAY $yout$. For example:

```
abc="ICCAP_ARRAY[6]"
abc[0]="foo"
abc[1]=1.235
abc[2]=2.33
abc[3]="foo"
abc[4]=3
abc[5]=-10.23919

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

fgh="ICCAP_ARRAY[1]"
fgh[0]="hello"

! fgh = {"hello"}
print array_equal_str(abc, fgh)

print array_copy(abc, fgh)

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}
! fgh = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_equal_str(abc, fgh)
```

Output:

```
0
0
1
```

Example:

```
fgh="ICCAP_ARRAY[2]"
fgh[0]="ICCAP_ARRAY[3]"
fgh[0][0]="foo"
fgh[0][1]=1.235
fgh[0][2]=2.33
fgh[1]="ICCAP_ARRAY[2]"
fgh[1][0]=0
fgh[1][1]= "ICCAP_ARRAY[4]"
fgh[1][1][0]="fee"
fgh[1][1][1]=-10.23919
fgh[1][1][2]=3
fgh[1][1][3]="foo"

array_copy(abc, fgh)
```

Result:

```
abc="ICCAP_ARRAY[2]"
abc[0]="ICCAP_ARRAY[3]"
```

```
abc[0][0]="foo"
abc[0][1]=1.235
abc[0][2]=2.33
abc[1]="ICCAP_ARRAY[2]"
abc[1][0]=0
abc[1][1]= "ICCAP_ARRAY[4]"
abc[1][1][0]="fee"
abc[1][1][1]=-10.23919
abc[1][1][2]=3
abc[1][1][3]="foo"
```

Example:

```
array_copy(abc[1], fgh)
```

Result:

```
fgh="ICCAP_ARRAY[2]"
fgh[0]=0
fgh[1]= "ICCAP_ARRAY[4]"
fgh[1][0]="fee"
fgh[1][1]=-10.23919
fgh[1][2]=3
fgh[1][3]="foo"
```

Example:

```
array_copy(abc[0], fgh[1][3])
```

Result:

```
fgh="ICCAP_ARRAY[2]"
fgh[0]=0
fgh[1]= "ICCAP_ARRAY[4]"
fgh[1][0]="fee"
fgh[1][1]=-10.23919
fgh[1][2]=3
fgh[1][3]="ICCAP_ARRAY[3]"
abc[1][3][0]="foo"
abc[1][3][1]=1.235
abc[1][3][2]=2.33
```

array_equal_num(x,y[,prec])

Returns 1 if the ICCAP_ARRAY x elements have the same double values as the corresponding elements of ICCAP_ARRAY y. Returns 0 if the ICCAP_ARRAY x and ICCAP_ARRAY y are not equivalent. The 3rd optional argument *prec* can be used to specify the double precision to compare the input arrays x and y with when determining their equivalency. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]=-4.23321
abc[1]=1.235
abc[2]=21
abc[3]=-10.23919

! abc = {-4.23321, 1.235, 21, -10.23919}

abc2="ICCAP_ARRAY[5]"
```

```
abc2[0]=-4.23321
abc2[1]=1.235
abc2[2]=21
abc2[3]=-10.23919
abc2[4]=0.3422

! abc = {-4.23321, 1.235, 21, -10.23919, 0.3422}

abc3="ICCAP_ARRAY[4]"
abc3[0]=-4.23321
abc3[1]=1.235
abc3[2]=21
abc3[3]=-10.24

! abc3 = {-4.23321, 1.235, 21, -10.24}

print array_equal_num(abc,  abc2, 3)
print array_equal_num(abc,  abc3, 2)
print array_equal_num(abc,  abc3, 5)
print array_equal_num(abc2, abc3, 3)
```

Output:

```
0
1
0
0
```

array_equal_str(x,y)

Returns 1 if the ICCAP_ARRAY x elements have the same string values as the corresponding elements of ICCAP_ARRAY y. Returns 0 if the ICCAP_ARRAY x and ICCAP_ARRAY y are not equivalent. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]="foo"
abc[1]=1.235
abc[2]="foo2"
abc[3]=-10.23919

! abc = {"foo", 1.235, "foo2", -10.23919}

abc2="ICCAP_ARRAY[5]"
abc2[0]="foo"
abc2[1]=1.235
abc2[2]="foo2"
abc2[3]=-10.23919
abc2[4]="foo3"

! abc2 = {"foo", 1.235, "foo2", -10.23919, "foo3"}

abc3="ICCAP_ARRAY[4]"
abc3[0]="foo"
abc3[1]=1.235
abc3[2]="foo2"
abc3[3]=-10.23919

! abc3 = {"foo", 1.235, "foo2", -10.23919}
```

```
print array_equal_str(abc, abc2)
print array_equal_str(abc, abc3)
print array_equal_str(abc2, abc3)
```

Output:

```
0
1
0
```

array_insert_at(x,y [,pos])

Returns 0 if successful and ICCAP_ARRAY x will be modified to include the data y inserted into the data array at the optional 3rd argument integer index pos. If the 3rd argument pos is not specified, the data y will be appended to the end of the ICCAP_ARRAY data array x. For example:

```
abc="ICCAP_ARRAY[5]"
abc[0]=1
abc[1]=2
abc[2]=3
abc[3]=3
abc[4]=12

print array_insert_at(abc,55,6)
! abc = {1,2,3,3,12}
print array_insert_at(abc,43,5)
! abc = {1,2,3,3,12,43}
print array_insert_at(abc,23.33,0)
! abc = {23.33,1,2,3,3,12,43}
print array_insert_at(abc,-55.34)
! abc = {23.33,1,2,3,3,12,43, -55.34}
print array_insert_at(abc,"foo",2)
! abc = {23.33,1,"foo",2,3,3,12, 43,-55.34}
```

Output:

```
-1
0
0
0
0
```

array_remove_all(x,y[,prec])

Returns 0 if the value y is found and removed in the array x. Returns -1 if unsuccessful. The ICCAP_ARRAY x will be updated to no longer contain all elements found in the array with the value y. If value y is a double value, then the optional 3rd argument $prec$ can be used to set what precision the function will use to search for the double value y in the array x. For example:

```
abc="ICCAP_ARRAY[6]"
abc[0]="foo"
```

```
abc[1]=1.235
abc[2]=2.33
abc[3]="foo"
abc[4]=3
abc[5]=-10.23919

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_all(abc, "unknown" )
! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_all(abc, "5")
! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_all(abc, "3")
! abc = {"foo", 1.235, 2.33, "foo", -10.23919}

print array_remove_all(abc, 2.33)
! abc = {"foo", 1.235, "foo", -10.23919}

print array_remove_all(abc, -10.239, 3)
! abc = {"foo", 1.235, "foo"}

print array_remove_all(abc, "foo")
! abc = {1.235}
```

Output:

```
-1
-1
0
0
0
0
```

array_remove_at(x,pos)

Returns 0 if successful and the dataset, complex 1x1 array, or ICCAP_ARRAY *x* with the data removed from the data array at argument integer index *pos*. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]=1
abc[1]=2
abc[2]="foo"
abc[3]=3
! abc = {1, 2, foo, 3}

print array_remove_at(abc, 2)
! abc = {1, 2, 3}

print array_remove_at(abc, 1)
! abc = {1, 3}

print array_remove_at(abc, 0)
! abc = {3}

print array_remove_at(abc, 0)
! abc = ""
! abc is no longer an ICCAP_ARRAY
```

Output:

```
0
0
0
0
```

array_remove_first(x,y[,prec])

Returns the integer position of the first occurrence of value y that is found in the array x and removed, or returns -1 if unsuccessful. The ICCAP_ARRAY x will be updated to no longer contain the first element found in the array to contain the value y on return. If value y is a double value, then the optional 3rd argument prec can be used to set what precision the function will use to search for the double value y in the array x for removal. For example:

```
abc="ICCAP_ARRAY[6]"
abc[0]="foo"
abc[1]=1.235
abc[2]=2.33
abc[3]="foo"
abc[4]=3
abc[5]=-10.23919

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_first(abc, "unknown" )
! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_first(abc, "5")
! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_first(abc, "3")
! abc = {"foo", 1.235, 2.33, "foo", -10.23919}

print array_remove_first(abc, 2.33)
! abc = {"foo", 1.235, "foo", -10.23919}

print array_remove_first(abc, -10.239, 3)
! abc = {"foo", 1.235, "foo"}

print array_remove_first(abc, "foo")
! abc = {1.235, "foo"}
```

Output:

```
-1
-1
4
2
3
0
```

array_remove_last(x,y[,prec])

Returns the integer position of the last occurrence of value y that is found in the array x and removed, or returns -1 if unsuccessful. The ICCAP_ARRAY x will be updated to no longer contain the last element found in the array to contain the value y on return. If value y is a double value, then the optional 3rd argument prec can be used to set what precision the function will use to search for the double value y in the array x for removal. For example:

```
abc="ICCAP_ARRAY[6]"
abc[0]="foo"
abc[1]=1.235
abc[2]=2.33
abc[3]="foo"
abc[4]=3
abc[5]=-10.23919

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_last(abc, "unknown" )
! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_last(abc, "5")
! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print array_remove_last(abc, "3")
! abc = {"foo", 1.235, 2.33, "foo", -10.23919}

print array_remove_last(abc, 2.33)
! abc = {"foo", 1.235, "foo", -10.23919}

print array_remove_last(abc, -10.239, 3)
! abc = {"foo", 1.235, "foo"}

print array_remove_last(abc, "foo")
! abc = {"foo", 1.235}
```

Output:

```
-1
-1
4
2
3
2
```

array_reorder (x,idxarr)

Given an ICCAP_ARRAY x of values and an ICCAP_ARRAY $idxarr$ of indices, this function reorders the elements of the ICCAP_ARRAY x using the array of indices $idxarr$. Returns 0 if array was successfully reordered. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]=-4.23321
abc[1]=1.235
abc[2]=21
abc[3]=-10.23919

! abc = {-4.23321, 1.235, 21, -10.23919}

idxabc="ICCAP_ARRAY[4]"
idxabc[0]=2
idxabc[1]=3
idxabc[2]=0
idxabc[3]=1

print array_reorder(abc, idxabc)

! abc = {21, -10.23919, -4.23321, 1.235}
```

Output:

```
0
```

array_rsort_num (x, prec[, idxArr])

Given an ICCAP_ARRAY x and no 3rd optional argument idxArr, this function will sort the ICCAP_ARRAY x in descending order using the given double precision, specified by the 2nd argument prec. The precision will be used to compare the array elements' double values during the sorting operation. If the 3rd optional argument idxArr is specified, then the ICCAP_ARRAY x will not be sorted but instead the function will return idxArr as an ICCAP_ARRAY with an array of sorted indices. Returns 0 if successful. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]=-4.23321
abc[1]=1.235
abc[2]=21
abc[3]=-10.23919

! abc = {-4.23321, 1.235, 21, -10.23919}

print array_rsort_num(abc, 5)

! abc = {21, 1.2345, -4.23321, -10.23919}

abc2="ICCAP_ARRAY[4]"
abc2[0]=-4.23321
abc2[1]=1.235
abc2[2]=21
abc2[3]=-10.23919

! abc2 = {-4.23321, 1.235, 21, -10.23919}

idxabc2=""
! idxabc2 =
```

```
print array_rsort_num(abc2, 5, idxabc2)

! abc2 = {-4.23321, 1.235, 21, -10.23919}
! idxabc2 = {2, 1, 0, 3}
```

Output:

```
0
0
```

array_rsort_str (x[, idxArr])

Given an ICCAP_ARRAY x and no 2^{nd} optional argument $idxArr$, this function sorts the ICCAP_ARRAY x in descending order comparing the array elements' string values. If the optional 2^{nd} argument $idxArr$ is specified, then the ICCAP_ARRAY x will not be sorted but instead the function returns $idxArr$ as an ICCAP_ARRAY with an array of sorted indices. Returns 0 if successful. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]="foo"
abc[1]="fee"
abc[2]="foo2"
abc[3]="faa"

! abc = {"foo", "fee", "foo2", "faa"}

print array_rsort_str(abc)

! abc = {"foo2", "foo", "fee", "faa"}

abc2="ICCAP_ARRAY[4]"
abc2[0]="foo"
abc2[1]="fee"
abc2[2]="foo2"
abc2[3]="faa"

! abc2 = {"foo", "fee", "foo2", "faa"}

idxabc2=""
! idxabc2 =

print array_rsort_str(abc2, idxabc2)

! abc2 = {"foo", "fee", "foo2", "faa"}
! idxabc2 = {2, 0, 1, 3}
```

Output:

```
0
0
```

array_sort_num (x, prec[, idxArr])

Given an ICCAP_ARRAY x and no 3^{rd} optional argument $idxArr$, this function sorts the ICCAP_ARRAY x in ascending order using the given double precision, specified by the 2^{nd} argument $prec$. The precision will be used to compare the array elements' double values during the sorting operation. If the 3^{rd} optional argument $idxArr$ is specified, then the ICCAP_ARRAY x will not be sorted but instead the function returns $idxArr$ as an ICCAP_ARRAY with an array of sorted indices. Returns 0 if successful. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]=-4.23321
abc[1]=1.235
abc[2]=21
abc[3]=-10.23919

! abc = {-4.23321, 1.235, 21, -10.23919}

print array_sort_num(abc, 5)

! abc = {-10.23919, -4.23321, 1.2345, 21}

abc2="ICCAP_ARRAY[4]"
abc2[0]=-4.23321
abc2[1]=1.235
abc2[2]=21
abc2[3]=-10.23919

! abc2 = {-4.23321, 1.235, 21, -10.23919}

idxabc2=""
! idxabc2 =

print array_sort_num(abc2, 5, idxabc2)

! abc2 = {-4.23321, 1.235, 21, -10.23919}
! idxabc2 = {3, 0, 1, 2}
```

Output:

```
0
0
```

array_sort_str (x[, idxArr])

Given an ICCAP_ARRAY x and no 2^{nd} optional argument $idxArr$, this function sorts the ICCAP_ARRAY x in ascending order comparing the array elements' string values. If the optional 2^{nd} argument $idxArr$ is specified, then the ICCAP_ARRAY x will not be sorted but instead the function returns $idxArr$ as an ICCAP_ARRAY with an array of sorted indices. Returns 0 if successful. For example:

```
abc="ICCAP_ARRAY[4]"
abc[0]="foo"
abc[1]="fee"
abc[2]="foo2"
abc[3]="faa"

! abc = {"foo", "fee", "foo2", "faa"}

print array_sort_str(abc)

! abc = {"faa", "fee", "foo", "foo2"}

abc2="ICCAP_ARRAY[4]"
abc2[0]="foo"
abc2[1]="fee"
abc2[2]="foo2"
abc2[3]="faa"

! abc2 = {"foo", "fee", "foo2", "faa"}

idxabc2=""
! idxabc2 =

print array_sort_str(abc2, idxabc2)

! abc2 = {"foo", "fee", "foo2", "faa"}
! idxabc2 = {3, 1, 0, 2}
```

Output:

```
0
0
```

ascii$

Converts ascii-coded characters into literal characters as entered into a text box.

chr$(x)

Converts the integer x to its equivalent ASCII string character.

colsof(x)

Returns an integer number of columns in a matrix, complex array of matrix data, or a data set x. For example:

```
complex def[4]
complex ghi.55[4]

print colsof(def)
print colsof(ghi)
```

Output:

```
1
5
```

complex_equal(x,y [,prec])

Returns 1 if the complex_array or dataset x elements have the same complex values as the corresponding elements of complex array or dataset y. Returns 0 if x and y are not equivalent. Use the 3rd optional argument *prec* to specify double precision when comparing the x and y data arrays. For example:

```
complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

complex jkl[5]
jkl[0]=-3.23+j*6
jkl[1]=1.000+j*2
jkl[2]=3+j*5
jkl[3]=2.3+j*1
jkl[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  6.000000E+000
!    1 (1,1)  1.000000E+000  2.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

x=complex_copy(def)
print complex_equal(def, x)
print complex_equal(def, jkl)
```

Output:

```
1
0
```

complex_insert_at(x,y [,pos])

Returns a new complex array or dataset with the data y inserted into a copy of the dataset or complex array x. If *pos*, the optional 3rd argument integer position is specified, the data y will be inserted at the index in the copy of the dataset or complex array specified by the x that is returned. If the 3rd argument *pos* is not specified, the data y will be appended to the end of the returned copy of the data set or complex array x. Only 1x1 matrix complex array data or datasets are supported.

The complex array or dataset x will not be modified by this function. For example:

```
complex def[2]
def[0]=1.000
def[1]=2.3+j*1

!Point Index   R:common       I:common
! 0 (1,1)  1.000000E+000  0.000000E+000
! 1 (1,1)  2.300000E+000  1.000000E+000

x=complex_insert_at(def, 3+j*5, 1)

!Point Index   R:common       I:common
! 0 (1,1)  1.000000E+000  0.000000E+000
! 1 (1,1)  3.000000E+000  5.000000E+000
! 2 (1,1)  2.300000E+000  1.000000E+000

y=complex_insert_at(x, 443.55)

!Point Index   R:common       I:common
! 0 (1,1)  1.000000E+000  0.000000E+000
! 1 (1,1)  3.000000E+000  5.000000E+000
! 2 (1,1)  2.300000E+000  1.000000E+000
! 3 (1,1)  4.435500E+002  0.000000E+000

z=complex_insert_at(y, "-3.23", 0)

!Point Index   R:common       I:common
! 0 (1,1) -3.230000E+000  0.000000E+000
! 1 (1,1)  1.000000E+000  0.000000E+000
! 2 (1,1)  3.000000E+000  5.000000E+000
! 3 (1,1)  2.300000E+000  1.000000E+000
! 4 (1,1)  4.435500E+002  0.000000E+000
```

complex_remove_all(x,y[,prec])

Returns a copy of the dataset or complex array x with all occurrences of real value y removed, or returns just a copy of the dataset or complex array x if value y was not found. If value y is a double value, then the optional 3rd argument *prec* can be used to set what precision the function will use to search for the double value y in the magnitude real data of the complex array or dataset x. For example:

```
complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000
```

```
x=complex_remove_all(def, 3+j*5)

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000

y=complex_remove_all(x, -3.23, 3)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  2.300000E+000  1.000000E+000

z=complex_remove_all(y, "2.3")

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
```

complex_remove_at(x,pos)

Returns a copy of the dataset or complex array x with the data removed at position x in the dataset or complex array. Only 1x1 matrix complex array data or datasets are supported. The complex array or dataset x will not be modified by this function. For example:

```
complex def[4]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000

x=complex_remove_at(def, 0)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000

y=complex_remove_at(x, 2)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000

z=complex_remove_at(y, 0)

!Point Index   R:common       I:common
!    1 (1,1)  3.000000E+000  5.000000E+000
```

complex_remove_first(x,y[,prec])

Returns a copy of the dataset or complex array x with the first occurrence of real value y removed, or returns just a copy of the dataset or complex array x if value y was not found. If value y is a double value, then the optional 3rd argument *prec* can be used to set what precision the function will use to search for the double value y in the magnitude real data of the complex array or dataset x. For example:

```
complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

x=complex_remove_first(def, 3+j*5)

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000
!    3 (1,1)  3.000000E+000  5.000000E+000

y=complex_remove_first(x, -3.23, 3)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  2.300000E+000  1.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000

z=complex_remove_first(y, "2.3")

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000

a=complex_remove_first(z, 3)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
```

complex_remove_last(x,y[,prec])

Returns a copy of the dataset or complex array x with the last occurrence of real value y removed, or returns just a copy of the dataset or complex array x if value y was not found. If value y is a double value, then the optional 3rd argument *prec* can be used

to set what precision the function will use to search for the double value y in the magnitude real data of the complex array or dataset x. For example:

```
complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

x=complex_remove_last(def, 3+j*5)

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000

y=complex_remove_last(x, -3.23, 3)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000

z=complex_remove_last(y, "2.3")

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000

a=complex_remove_last(z, 3)

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
```

complex_reorder (x,idxarr)

Given a complex array or dataset x and an ICCAP_ARRAY *idxarr* of indices, this function creates a copy of the dataset or complex array x and reorder the elements of the copied data array using the array of indices *idxarr*, and then returns that reordered copy of the data array x. For example:

```
complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5
```

```
!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

idxdef="ICCAP_ARRAY[5]"
idxdef[0]=4
idxdef[1]=3
idxdef[2]=0
idxdef[3]=2
idxdef[4]=1

x=complex_reorder(def, idxdef)

!Point Index   R:common       I:common
!    0 (1,1)  3.000000E+000  5.000000E+000
!    1 (1,1)  2.300000E+000  1.000000E+000
!    2 (1,1) -3.230000E+000  0.000000E+000
!    3 (1,1)  3.000000E+000  5.000000E+000
!    4 (1,1)  1.000000E+000  0.000000E+000
```

complex_rsort (x,prec[,idxArr])

Given a complex array or dataset x, this function creates a copy of the dataset or complex array x, then sorts the elements in descending order, and then returns the sorted copy. The 2^{nd} argument *prec* is used to specify the double precision to use when comparing elements during the sorting of the data array elements. The 3^{rd} optional argument *idxArr* if specified, will be returned as an ICCAP_ARRAY of sorted integer indices. For example:

```
complex def[5]
def[0]=1.000
def[1]=-3.23
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1) -3.230000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

x=complex_rsort(def,4)

!Point Index   R:common       I:common
!    0 (1,1)  3.000000E+000  5.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000
!    3 (1,1)  1.000000E+000  0.000000E+000
!    4 (1,1) -3.230000E+000  0.000000E+000
```

```
idxdef=""
y=complex_rsort(def, 4, idxdef)

!Point Index   R:common       I:common
!    0 (1,1)  3.000000E+000  5.000000E+000
!    1 (1,1)  3.000000E+000  5.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000
!    3 (1,1)  1.000000E+000  0.000000E+000
!    4 (1,1) -3.230000E+000  0.000000E+000

! idxdef = {2,4,3,0,1}
```

complex_sort (x,prec[,idxArr])

Given a complex array or dataset x, this function creates a copy of the dataset or complex array x, and sort the elements in ascending order, and then returns that sorted copy of the complex array or dataset x. The 2^{nd} argument *prec* is used to specify the double precision to use when comparing elements during the sorting of the data array elements. The $3rd$ optional argument *idxArr*, if specified, will be returned as an ICCAP_ARRAY of sorted integer indices. For example:

```
complex def[5]
def[0]=1.000
def[1]=-3.23
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1)  1.000000E+000  0.000000E+000
!    1 (1,1) -3.230000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

x=complex_sort(def,4)

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000
!    3 (1,1)  3.000000E+000  5.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

idxdef=""
y=complex_sort(def, 4, idxdef)

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  2.300000E+000  1.000000E+000
!    3 (1,1)  3.000000E+000  5.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000
```

```
! idxdef = {1, 0, 3, 2, 4}
```

dataset

Enables you to access the dataset referred to by a string. A second argument may be specified which is a variable to receive any error string normally going to a red error box.

exp

e is raised to the power specified by the argument.

fix_path$

Guarantees a path appropriate for the current architecture.

fix_path$(<path>)

Returns a string based on the passed in *<path>*, which is either a filename or a directory. The returned string will be the same filename or directory converted to the local architecture.

On UNIX, this converts Windows directory separators '\' to UNIX directory separators '/'. On the PC, it does the opposite and also takes care of any cygwin path dependencies.

Since IC-CAP uses the cygwin shell to execute the PEL *system()* and *system$()* commands, certain calls have cygwin dependencies. For example,

```
print system$("echo $HOME")
```

may return something like */cygdrive/d/users/icuser*, which does not have the *Windows* feel. Therefore, you may want to rewrite the PEL as follows:

```
print fix_path$(system$("echo $HOME"))
```

which returns *d:\users\icuser* using the above example.

imag

Extracts the imaginary part of a data set, matrix, or complex number.

imaginary

Extracts the imaginary part of a data set, matrix, or complex number.

index_of(x,y,pos[,prec])

Returns the integer index of the first element found starting at position *pos* that has the same value as *y* in the ICCAP_ARRAY, dataset, or complex array *x*. If no elements are found in the data array *x*, then -1 is returned. The 2nd argument *y* can be a string or a double value. If value *y* is a double value, then the optional 4th argument *prec* can be used to set what precision the function will use to search for the element with the same double value *y* in the ICCAP_ARRAY, dataset, or complex array *x*. For example:

```
abc="ICCAP_ARRAY[6]"
abc[0]="foo"
abc[1]=1.235
abc[2]=2.33
abc[3]="foo"
abc[4]=3
abc[5]=-10.23919

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print "ICCAP_ARRAY output:"
print index_of(abc, "unknown", 0)
print index_of(abc, 3, 0)
print index_of(abc, 3, 5)
print index_of(abc, -10.24, 0, 3)
print index_of(abc, "foo", 0)
print index_of(abc, "foo", 1)

complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000

print "Complex array output:"
print index_of(def, "2.3", 4)
print index_of(def, "2.3", 0)
print index_of(def, 3, 0, 4)
print index_of(def, 3, 3, 4)
```

Output:

ICCAP_ARRAY output:

```
-1
4
-1
5
0
3
```

Complex array output:

```
-1
3
2
4
```

last_index_of(x,y[,prec])

Returns the integer index of the last element that has the same value as y in the ICCAP_ARRAY, dataset, or complex array x. If no elements are found in the data array x, then -1 is returned. The 2nd argument y can be a string or a double value. If value y is a double value, then the optional 3rd argument *prec* can be used to set what precision the function will use to search for the element with the same double value y in the ICCAP_ARRAY, dataset, or complex array x. For example:

```
abc="ICCAP_ARRAY[6]"
abc[0]="foo"
abc[1]=1.235
abc[2]=2.33
abc[3]="foo"
abc[4]=3
abc[5]=-10.23919

! abc = {"foo", 1.235, 2.33, "foo", 3, -10.23919}

print "ICCAP_ARRAY output:"
print last_index_of(abc, "unknown")
print last_index_of(abc, 3)
print last_index_of(abc, -10.24, 3)
print last_index_of(abc, "foo")

complex def[5]
def[0]=-3.23
def[1]=1.000
def[2]=3+j*5
def[3]=2.3+j*1
def[4]=3+j*5

!Point Index   R:common       I:common
!    0 (1,1) -3.230000E+000  0.000000E+000
!    1 (1,1)  1.000000E+000  0.000000E+000
!    2 (1,1)  3.000000E+000  5.000000E+000
!    3 (1,1)  2.300000E+000  1.000000E+000
!    4 (1,1)  3.000000E+000  5.000000E+000
```

```
print "Complex array output:"
print last_index_of(def, 35.355, 4)
print last_index_of(def, "2.3")
print last_index_of(def, 3.0, 4)
print last_index_of(def, "3.00")
```

Output:

ICCAP_ARRAY output:

```
-1
4
5
3
```

Complex array output:

```
-1
3
4
4
```

log

Computes log base *e*.

log10 or *lgt*

Computes log base *10*.

lookup_instr_table_val or *lookup_instr_table_val_eval*

Enables you to access the value of a field in an instrument options table. The first argument is the path to the table. The second argument is the field in the table (see "Set Table Field Value" on page 970 for syntax to specify the field name). An optional third argument may be specified which is a variable to receive any error string normally going to a red error box. *lookup_instr_table_val* returns NUMPTS if NUMPTS is a variable in # of Points. *lookup_instr_table_val_eval* returns 100 (presuming NUMPTS evaluates to 100).

lookup_obj_attribute

Enables you to access the state or attributes of a plot. The first argument is the object and the second argument is the keyword. The syntax is:

```
X=lookup_obj_attribute("<Object>","Keyword")
```

For a Multiplot, specify the plot number in brackets after the object:

```
X=lookup_obj_attribute("<Object>[N]", "Keyword")
```

For example:

```
X=lookup_obj_attribute("/my_model/
my_dut/my_setup/my_multiplot/
Multiplot[1],"UserSelectedRegion")
```

This example returns the coordinates of the white box that the user drew on the second plot (index=1) of the Multiplot my_multiplot.

The following table lists supported keywords.

Object	Keyword	Return Value
model	POWindowOpen	Int flag 0/1
plot	POEnable	Int flag 0/1
plot	ErrorEnable	Int flag 0/1
plot	IsErrorRelative	Int 1 is error is relative, 0 if error is absolute
plot	ErrorRegion	Data set array of 5 points X1,x2,y1,y2, color Color always returns 3 (green)
plot	UserRegion/<Name>	Data set array of 5 points X1,x2,y1,y2, color
plot	PORegionNumber	Number of Plot Optimizer regions
plot	PORegion[N]	Dataset array of 4 points X1,x2,y1,y2
plot	UserSelectedRegion (white box)	Dataset array of 6 points Returns the coordinate of the white box: X1,x1,y1,y2,z1,z2 Where z1,z2 are the coordinates with respect to the Y2 axis

Object	Keyword	Return Value
plot	UserSelectedPoint	Dataset array of 3 points • selected point in the dataset • selected trace (0-8 with 8 being the Y2 trace) • selected type: 0 (transform) 1(measured) 2 (simulated)
plot	GraphicMouseState	Returns 2 if a white box is selected
plot	XAxisDisplayType	-1 (Unknown) 0 (Linear), 1(Log) or 2 (dB)
plot	YAxisDisplayType	-1 (Unknown) 0 (Linear), 1(Log) or 2 (dB)
plot	Y2AxisDisplayType	-1 (Unknown) 0 (Linear), 1(Log) or 2 (dB)
Multiplot only	SelectedPlot	Returns selected plot

lookup_par

Enables you to access the value of a parameter referenced by a string. A second argument may be specified which is a variable to receive any error string normally going to a red error box.

lookup_table_val or *lookup_table_val_eval*

Enables you to access the value of a field in an input, output, plot, parameter, or optimizer table. The first argument is the path to the table. The second argument is the field in the table (see “Set Table Field Value” on page 970 for syntax to specify the field name). An optional third argument may be specified which is a variable to receive any error string normally going to a red error box. *lookup_table_val* returns NUMPTS if NUMPTS is a variable in # of Points. *lookup_table_val_eval* returns 100 (presuming NUMPTS evaluates to 100).

lookup_var

Enables you to access the value of a variable referenced by a string. A second argument may be specified which is a variable to receive any error string normally going to a red error box.

lwc$(x)

Returns the lower case version of the string x. For example:

```
print lwc$("Hello")
```

Output:

```
hello
```

mag or *magnitude*

Computes the magnitude for a complex number, or for each complex number in a matrix, data set, or data set of matrices.

max

Takes any number of arguments, as in HP BASIC. The argument list can be a mixture of scalars and data sets, and the function returns the maximum value found in any of them. This always returns a single real number, and only the real parts are considered. If matrices are received, only the 1,1 points are considered.

mdata(expr)

Returns the measured part of the argument *expr*.

min

Behaves like max, but returns the minimum value.

ph or *phase*

Computes the phase angle in radians for a complex number, or for each complex number in a matrix, data set, or data set of matrices.

real

Extracts the real part of a data set, matrix, or complex number.

rowsof(x)

Returns an integer number of rows in a matrix, complex array of matrix data, or a data set x. For example:

```
complex def[4]
complex ghi.55[4]

print rowsof(def)
print rowsof(ghi)
```

Output:

```
1
5
```

sdata(expr)

Returns the simulated part of the argument *expr*.

size

Returns the number of points in a data set, which is an integer.

sizeof(x)

Returns an integer number of elements in a variable *ICCAP_ARRAY*, or a complex array of data, or a data set. Returns 0 if x doesn't represent a data array or if the data array is empty or both. For example:

```
abc="ICCAP_ARRAY[5]"
abc[0]=1
abc[1]=2
abc[2]=3
abc[3]=3
abc[4]=12

complex def[4]
def[0]=1.000
def[1]=1+j*1
def[2]=5
def[3]=6

complex ghi.55[3]

x=1.354529

print sizeof(abc)
```

```
print sizeof(def)
print sizeof(ghi)
print sizeof(x)
```

Output:

```
5
4
3
0
```

sqrt

Square root function. Complex and negative quantities produce correct complex or imaginary results.

strlen(x)

Returns the number of characters in the string x. For example:

```
print strlen("Hello")
```

Output:

```
5
```

strpos(x,y)

Returns the index of the first occurrence of substring *str2* found in string *str1*. An optional third argument may be specified which is an integer starting position that should be greater than or equal to 1. The starting position can be used to specify the starting index within the string *str1* to start searching for substring *str2*. For example:

```
print strpos("Hello","ell")
print strpos("Hello","He")
print strpos("Hello","dog")
print strpos("Hello","l",1)
print strpos("Hello","l",4)
print strpos("Hello","l",5)
```

Output:

```
2
1
0
3
4
0
```

strrpos(str1,str2 [,endpos])

Returns the index of the last occurrence of substring *str2* found in string *str1*. An optional third argument may be specified which is an integer end position that should be greater than or equal to 1. The end position can be used to specify the last index within the string *str1* to search for the last occurrence of substring *str2*, using the search range of index 1 to *endpos*. For example:

```
print strrpos("Hello","ell")
print strrpos("Hello","He")
print strrpos("Hello","dog")
print strrpos("Hello","l",1)
print strrpos("Hello","l",4)
print strrpos("Hello","l",5)
```

Output:

```
2
1
0
0
4
4
```

substr$(x,start,stop)

Extracts the substring from the *start* index to the *stop* index from the string *x*. The value “1” refers to the first character in the string. If *stop* is omitted, *substr$* returns the string from *start* to the end of the string. For example:

```
x="Hello"
print substr$(x,4)
print substr$(x,2,4)
```

Output:

```
lo
ell
```

sys_path$

Guarantees a path appropriate for passing to the system$() or system() command.

sys_path$(<path>)

Returns a string based on the passed in *<path>*, which is either a filename or a directory. The returned string will be the same filename or directory converted to the proper format for the *system$()* or *system()* function.

Since IC-CAP uses the cygwin shell to process the PEL *system$* and *system* calls, PC style paths may not work properly when passed as arguments to system functions.

For example, if the user's response to

```
LINPUT "Enter a filename",path
print system$("ls -al " & path)
```

is:

foobar — the code functions properly.

/tmp/foobar — the code functions properly because IC-CAP insures */tmp* and */var/tmp* exist in the system call environment.

d:foobar — the code does not function properly.

However, the following rewrite

```
LINPUT "Enter a filename",path
print system$("ls -al " & sys_path$(path))
```

insures that the *system$()* call actually sees */cygdrive/d/foobar* even when the user types *d:foobar*.

system

Accepts a string argument, which is a shell command to invoke. You can employ all valid shell I/O redirection and other shell syntax within the string argument. It returns an integer, which is the exit status of the shell. If the shell command generates output, it is printed in the terminal window from which the IC-CAP program was started; refer to *system$*. On the PC, if a syntax error appears, turn on screen debug for additional information.

system

Accepts a string argument, which is a shell command to invoke. You can employ all valid shell I/O redirection and other shell syntax within the string argument. It returns an integer, which is the exit status of the shell. If the shell command generates output, it is printed in the terminal window from which the IC-CAP program was started; refer to *system$*. On the PC, if a syntax error appears, turn on screen debug for additional information.

system$

Similar to *system*; it captures the command's output, instead of letting it go to the terminal window. Instead of returning an integer, it returns the output that the shell command generated. For example:

```
my_date$ = system$("date") ! get date
com$="echo "&my_date$&"|cut -c 5-7"
month$ = system$(com$) ! substring 5-7
```

On the PC, if a syntax error appears, turn on screen debug for additional information.

trim$(x,chars)

Where x is a string and *chars* is a string containing characters to be trimmed from x. This function trims the unwanted characters from the beginning and end of the string. The parameter for *chars* is optional. If *chars* is omitted, the default is to remove spaces from the beginning and end of the string. For example:

```
x="   stuff here   "
print trim$(x)
y="////stuff here__//__//"
print trim$(y)
print trim$(y,"/_")
```

Output:

```
stuff here
////stuff here__//__//
stiff here
```

upc$(x)

Returns the string x with all upper case characters. For example:

```
print upc$("Hello")
```

Output:

```
HELLO
```

val

Generates a number, given a string representation of a simple (not expression) integer, floating point, or complex number. For example:

```
linput "give a number",x$
x = val(x$)
```

val$

Generates a string, given a numeric expression. In conjunction with the & operator (string concatenation), it can be useful for formatting. The optional second argument can either be an integer or a string.

- If no optional argument is given, the conversion uses the %g printf conversion (see printf() man page for details). The number is converted with WORKING_PRECISION digits of precision. If WORKING_PRECISION is not set, 6 digits are used.
- If the second argument is an integer, then the integer is interpreted as the number of digits of precision to use in a %g printf() conversion (see printf() man page for details).
- If the second argument is *%nnICFMT* where *nn* are optional integers, then the number is converted to a string according to IC-CAP default conversion routine, which uses unit multipliers (e.g., *1.23e-12* is converted to *1.23p*). The optional *nn* specifies the number of digits of precision. If *nn* is less than 4, it is clamped to 4. If *nn* is omitted, then WORKING_PRECISION digits are used, if WORKING_PRECISION is not defined, 4 digits will be used.

- If the second argument is any other string, it should contain exactly one of %e, %E, %g, %G, or %f. See the *printf()* man page for optional modifiers to these formats that specify the number of digits and spacing.

Examples:

```
x=1.23456789e-12
print val$(x,"%ICFMT") ! 1.235p (Assuming WORKING_PRECISION
not set)
print val$(x,"%1ICFMT")! 1.235p (clamped to 4)
print val$(x,"%8ICFMT") ! 1.2345679p (8 digits total)
print val$(x,"abc %ICFMT") ! abc ICFMT (‘abc ’ on Linux)
(uses printf syntax)
print val$(x,"%e") ! 1.234568e-012 (printf format ignores
WORKING_PRECISION)
print val$(x,"%.3e") ! 1.235e-012 (specify 3 digits after
decimal)
print val$(x,"The number is %+12.4g.") !The number is
+1.235e-012. (12 positions for entire number and +)
print val$(x) ! 1.23457E-012 (6 digits of precision by
default)
print val$(x,7) ! 1.234568E-012
```

NOTE Real and complex scalars and data sets are accepted by all functions with the following exceptions: *system*, *system$,* and *val* expect to receive string data, and *val$* expects a scalar number.

Built-In Constants

Several constants are recognized. Like statement names and built-in function names, these are reserved words (for example, you should not attempt to name a variable *pi).* The recognized constants are:

```
PI  or  pi
2PI  or  2pi
J or j (square root of -1)
```

Expressions

As explained in the *Data Types* section, each type of data can be considered a simple expression. The primitive data types can make up more complex expressions by applying functions (such as *log*, or operators such as +). In this section, *expr* denotes an expression; *string_expr* denotes a string expression.

(expr) *expr + expr* *expr - expr* *expr * expr*

Parentheses force precedence and group expressions.

expr / expr *expr//expr*

IC-CAP objects, including data sets, can be named using a slash (/). These same data sets can be used as arguments in a divide operation. To ensure the slash is understood as the divide operator, surround it with white space, or enter a double slash (//). If the slash is followed by a digit, divide is also understood, because a data set name in IC-CAP cannot start with a digit. The expression *(ic)/(ib)* is an example of another technique.

expr ^ expr *expr ** expr*

These operators express exponentiation, and are equivalents.

string_expr & string_expr

As in HP BASIC, this operator performs string concatenation.

log(expr) Performs a natural log function. For more information, refer to "Built-in Functions" on page 712 and "Calls to the Function Library" on page 749.

To complete a computation, most operations make reasonable attempts to promote certain operands. For example, *ib + 2e-6* promotes the scalar number *2e-6* to be a data set that, in turn, can be added to the data set *ib*.

For most arithmetic operations performed on a data set, the function or operator is applied point-by-point, producing a data set. The behavior of individual functions in this regard is clarified in their individual descriptions in "Built-in Functions" on page 712.

There are some limitations in the usage of the 5 basic arithmetic operators in working with data sets. For example:

- If *ic* is a data set, re-write *3//ic* as *3*ic^ -1*.
- The expression *ic^ib* is not supported when both operands are data sets.
- None of the binary operators `*/+-^` support an operation between a matrix and a data set.

The arithmetic in Programs is generally a complex floating point. Therefore, it is possible to see unexpected residue from integer or real arithmetic. For example:

```
print (0+j)^2
```

may produce

```
-1+j*1.22461E-16
```

rather than

```
-1+j*0
```

This is due to finite precision in the library function that handles exponentiation of complex quantities.

Because complex arithmetic is used, success can occur where a function would be expected to fail in real arithmetic. For example

```
acsh(.5)
```

yields

```
0+j*1.05
```

The complex arithmetic provides a wider domain of valid inputs, but in cases where a real input should produce a real output, the complex arithmetic is indistinguishable from real arithmetic.

CAUTION Using the binary operators + and - (which have a higher precedence when used with the j notation) will produce unexpected results.

```
 -1+j2 == -1-j*2
(-1)+j2 == -1+j*2
```

Boolean Expressions

The expressions in this section can be used in the branching constructs (*IF*, *IF...ENDIF*, and *WHILE...ENDWHILE*), or can be used to generate the quantities *0* and *1*. The abbreviation *bool_expr* denotes a boolean expression.

NOTE There is a distinction between the = operator (used for assignment) and the == operator. BASIC uses = for both assignment and comparison.

In some circumstances, == may not behave as expected. For example, if you repeatedly increment the quantity 0.3 by the amount 0.025, the results may be slightly less (in the 15th decimal place) than the expected sequence of values: 0.325, 0.350, ... , 0.4. Under these circumstances, == may yield FALSE unexpectedly. This is an inherent problem of expressing decimal numbers in binary floating point format.

expr == *expr*	This operator tests for equality and can be used with string, integer, double, complex, and matrix types.
expr <> *expr*	This operator tests for inequality and can be used with string, integer, double, complex, and matrix types.

expr > *expr* *expr* >= *expr* *expr* < *expr* *expr* <= *expr*

These operators designate the standard comparison operation found in BASIC languages and can be used with integers, doubles, and complex quantities. With complex quantities, imaginary parts are discarded. (You can apply the *mag* function to each quantity to compare magnitudes of complex quantities.)

bool_expr AND bool_expr bool_expr OR bool_expr NOT boolean_expr

Any non-zero integer, double, or complex number is considered TRUE. For example:

```
IF 2 THEN PRINT 'hi' ! this always prints
```

A string with length >0 is TRUE. For example:

```
IF "Hello world" THEN PRINT "HI TO YOU TOO"
```

prints the second expression in the string

```
HI TO YOU TOO
```

Operators Precedence

The following is a list of operators in decreasing order of precedence. Operators listed on the same line have equal precedence.

( ) [ ]	Function calls, and array indexing, respectively
^ **	Exponentiation
+ – &	The ampersand (&) is for string concatenation
== <> < <= > >=	Comparison operators
NOT	
AND	
OR	
=	Assignment

For example, it is TRUE that:

```
-2^4 == -16
```

because the precedence of ^ exceeds that of – .

Calls to the Function Library

Any function in IC-CAP's Function Browser can be called, such as *sin, cos,* and *RMSerror*. This greatly expands the availability of functions in expressions, Programs, and Macros. Some examples are:

```
x = sin(pi/4)   ! x takes on the value .707...
x = linfit(ic,vc,0)
! x becomes a temporary data set with 2 points
print x[0] , x[1]   ! slope and intercept are printed
```

To review the arguments used in a function, refer to Chapter 8, "IC-CAP Functions," or create a stand-alone transform that uses the desired function and look at the resulting transform editor. For details on this procedure, refer to the section "Defining Transforms" in the *User's Guide*. To call the library function in a Program, Macro, or table element, supply arguments in the same order shown in the editor.

The functions may expect some data set arguments, some real number arguments, and some strings or Model or DUT parameter names. Expressions can be used for the data set arguments and real number arguments. For the parameter names, use actual parameter names, IC-CAP system variable names, or quoted strings, string variables, or string expressions. If a function requires a string as a flag or switch of some sort, quote it. Otherwise the system thinks you are referring to an identifier such as a Model parameter, a system variable, or a temporary variable in a Program or Macro. The following example might clarify this point:

```
! TwoPort requires strings as second and third arguments
! string argument dictates what type conversion to do
x = TwoPort(S_out,"S","Y")   ! this is OK
x = TwoPort(S_out,S,Y)   ! this is not, although...
S = "S"   ! initialize local variables S and Y
Y = "Y"
x = TwoPort(S_out,S,Y)   ! now this is OK
```

This point is mentioned because the quotation marks are not necessary if you use *TwoPort* as the function in a simple stand-alone Transform. The only other function that is like *TwoPort* in this regard is *USERC_system,* which requires a string to use as an operating system command.

Spell calls to functions contained in IC-CAP's Function List must be spelled exactly as in the Function List.

The result from a call to a function in the library is usually a data set. For example:

```
x = linfit(vc:log(ic.m),0)
! get slope and intercept for log(ic.m)
print x[0]   ! print the slope of log(ic.m)
```

On the other hand, there are 2 cases in which the result of a library function is a single number or matrix, and not a data set. This makes library function calls more convenient, or usable within expressions in table elements. For example:

```
x = sin(pi/4)   ! x is now .70711 ...
x = mean(ic.s)   ! x is the average current value in ic.s
```

In the first example, *sin* is a function that can sometimes return a data set, if a data set is provided. In this example though, the input is a scalar number. Therefore, the system initializes x with a scalar number. A number of other functions behave like *sin* in this respect. They can be identified in the IC-CAP Functions List, because the *Output* of these functions is said to be a single number or an array, dependent on the Input Arguments.

In the second example, *mean* receives a data set as input. However, by definition it always produces a scalar, so x is initialized as a single number, and not a data set. A call to the *variance, correlation,* or *RMSerror* functions also produces a single number, and not a data set.

Some library functions, particularly extractions, yield null data sets; they do not appear to generate data, but they set parameters to new values.

10
File Structure and Format

File Structure 752

This chapter describes the format of the IC-CAP *.mdl* file and associated files that can be written to and read from the system. When read into the system, these files restore IC-CAP to a previously saved state. Knowledge of the design of these files allows advanced users to perform many creative modifications to an IC-CAP configuration.

File Structure

All files used by IC-CAP are stored in an ASCII format that can be accessed by standard HP-UX tools and editors. IC-CAP Model files have a user-defined name; the extension is assigned by the system. The following table lists the file types and extensions.

Table 73 IC-CAP File Types and Extensions

File Type	Extension	File Type	Extension
Dataset	.ds	Data management	.mdm
Hardware	.hdw	Setup	.set
Model	.mdl	Input	.inp
Circuit	.cir	Output	.out
Model Parameters	.mps	Transform	.xfm
Macro	.mac	Plot	.plt
DUT	.dut	Instrument Options	.iot
DUT Parameters	.dps	Variables Table	.vat
Test Circuit	.tci	Input	.inp
Statistical data	.sdf		

The *.mdl* file is a combination of the file types listed below it. If all Models currently loaded are saved together, they are put in a single *.mdl* file. The complete Model file contains a circuit description, a model parameter set, Macros, and DUT descriptions. The DUT description in turn contains a DUT parameter set, a Test Circuit, and Setups. The Setups contain Inputs, Outputs, Transforms, and Plots.

The hardware description is global to IC-CAP and is not a part of a Model file. It can be saved in a *.hdw* file. It is also found in the *.icconfig* file in the user's home directory. In

addition to the hardware description, this file contains values of system variables, and status information for windows that are directly available from the Main Menu.

The individual major sections of the complete Model file begin with the word *LINK* followed by the type (for example, Model or *DUT*) and a name. The supporting information under this defines the appropriate configuration for IC-CAP. The hierarchy of related items in each file is defined by sets of
braces { }. A major section title is followed by an open brace { and continues until the complementary closing brace }.

Within a section there are several key words that indicate the function of the associated information. When a single key word is on a line, the associated information is on the lines below. For some key words, their associated information is in fields to the right only, while for others, associated information is in fields to the right and lines below. These key words are summarized in the following table.

When editing an IC-CAP Model file, key words and braces must be in the correct locations for the file to be correctly read into IC-CAP. Editing the file with a text editor can be quite productive in some areas. When developing large Program Transforms or Macros, you may find it more convenient to create these with an editor outside of IC-CAP and read them in. When doing this, begin each line of text in your Program Transform or Macro with the pound sign (#).

Table 74 Key words in the IC-CAP File Structures

Key Word	Definition
LINK	major IC-CAP building block
applic	application window that can be opened by IC-CAP
subapp	title within an application
TABLE	collection of user-modifiable elements

Table 74 Key words in the IC-CAP File Structures (continued)

Key Word	Definition
element	user-programmable field (input box)
HYPTABLE	table that is dynamically configured by IC-CAP
BLKEDIT	block editor text follows (note: leading space in text)
CNTABLE	connection table—not currently used in IC-CAP
PSTABLE	parameter set table
param	model parameter name and value
data	configuration data follows belonging to the LINK item
dataset	collection of numerical data
datasize	dimensional information for a dataset
type	MEASured, SIMUlated, or COMMON data points to follow
point	individual data value—index, row, column, real value, imaginary value
list	this item is dependent on the owning LINK item
member	the owning LINK item is dependent on this item

Example File

The following truncated Model file illustrates the structure described. Comments enclosed in angle brackets < > describe the file contents; they are not part of the actual IC-CAP file. Variable Tables or lines that start with *applic* or *subapp* are optional. It is not necessary for these lines to be present for a file to be successfully read by IC-CAP.

```
{ PSTABLE "Parameter Table"
{
}
}
}
}
Link DAT "idvd"   <DAT is internal name for Setup>
{
LINK MODEL "diode"   <first line of an IC-CAP .mdl file>
{
applic "Edit" 1 83 194  <main model window is open & at pixels 83,194>
subapp "dset_tile" 1  < DUT-Se tup tile is open>
TABLE "Variable Table"  <Variable Table for Model "diode">
{
element 0 "Name" "SIMULATOR"
element 0 "Value" "spice2"
element 1 "Name" ""
element 1 "Value" ""
}
LINK CIRC "Circuit"  <circuit description starts here>
{
applic "Edit" 0 12 328
subapp "Circuit" 1
data
{
circuitdeck
{
D1  1 = A  2 = C  DIODE   <all lines in circuit have a leading space>
.MODEL DIODE D
+ IS = 1E-14
+ N = 1.0
}
}
}  <circuit description ends here>
Link PS "Parameter Set"
{
applic "Edit" 0 7 137
subapp "Parameter Table" 1
data
{
PSTABLE "Parameter Table"
{
param IS  10.01f
param N  999.7m
}
}
}
Link DUT "dc"
{
applic "Edit" 0 -1 -1 <DUT editor is closed, has not been opened yet>
applic "Edit Variables" 0 -1 -1
subapp "setup_list" 1
Link TCIRC "Test Circuit"
{
subapp "Test Circuit" 0
data
{
```

```
circuitdeck
{
}  <end test circuit deck>
}  <end data section>
}  <end Test Circuit>
Link DPS "Device Parameter Set"
{
subapp "Parameter Table" 1
data
applic "Edit" 0 382 136  <Setup "idvd" is closed>
applic "Instrument Options" 0 -1 -1 <instrument options table not opened yet>
applic "Edit Variables" 0 -1 -1     <variables editor not opened yet>
subapp "SWEEP" 1
subapp "OUT" 1
subapp "XFORM" 1
subapp "PLOT" 1
subapp "Instrument Table List" 1
subapp "Variable Table" 1
Link SWEEP "va"   <Input sweep specification starts here>
{
applic "Display Data" 0 -1 -1
subapp "Edit Sweep Info" 1
subapp "Display Data" 1
data
{
HYPTABLE "Edit Sweep Info"  <start of dynamic table definition>
{
element "Mode" "V"
element "Sweep Type" "LIN"
}
HYPTABLE "Edit Sweep Mode Def"
{
element "+ Node" "A"
element "- Node" "GROUND"
element "Unit" "SMU1"
element "Compliance" " 100.0m"
}
HYPTABLE "Edit Sweep Def"
{
element "Sweep Order" "1"
element "Start" " 300.0m"
element "Stop" " 1.000 "
element "# of Points" "29"
element "Step Size" " 25.00m"
}
}  <end of dynamic table definition>
list XFORM "extract" <Transform "extract" is dependent on this Input>
list PLOT "i_vs_v"     <Plot has similar dependency>
}  <Input specification "va" ends here>
<repeat of similar Input not shown>
Link OUT "ia"   <Output specification starts here>
{
< file contents here similar to Input case & not shown>
dataset   <start of measured and simulated data>
{
datasize BOTH 29 1 1 <key: type #-of-points #-of-rows #-of-columns>
type MEAS   <measured data>
<key: index row column real imaginary>
point 0 1 1 1.09023e-09 0 <data point 0 has single value real number>
point 1 1 1 2.86573e-09 0   <note: s-parameters would have 4 values per point>
point 2 1 1 7.53339e-09 0 <corresponding to s11 s12 s21 and s22
```

```
point 3 1 1 1.98044e-08 0 <would be complex (real & imag) values>
point 4 1 1 5.20644e-08 0
<other data points not shown>
type SIMU   <simulated data>
point 0 1 1 1.09513e-09 0
point 1 1 1 2.87943e-09 0
<other data points not shown - same number as MEAS>
}
}
list XFORM "optim_is_n"  <Transform "optim_is_n" is dependent upon this Output>
list PLOT "i_vs_v"  <Plot has similar dependency>
}
Link XFORM "extract"  <extraction Transform starts here>
{
data
{
HYPTABLE "Link Transform"
{
element "Function" "Program"
}
BLKEDIT "Program Body" <prog body starts here - note leading space>
{
 ! Program Transform to extract IS, N, RS
 ! from forward diode I-V characteristics
 !
 ! Note: print statements go to the
 !       window used to start IC-CAP
print "Example Program Transform to extract DC Diode Parameters"

index = 0   ! array index
 !
 ! pick 2 low current points for IS & N
 ! to be extracted from
v1 = va[index]   ! 1st voltage step
WHILE v1 < 0.4   ! get first data
   index = index + 1   !  point pair
   v1 = va[index]
END WHILE
i1 = ia[index]
   < more program exists but is not shown>
print "... end of program Transform extraction ..."

}
dataset
{
datasize COMMON 29 1 1    <key: type #-of-points #-of-rows #-of-columns>
type COMMON      <COMMON specification means that the same data is >
point 0 1 1 0 0  <used to represent measured & simulated data. >
point 1 1 1 0 0  <However, the data space is not used by this >
point 2 1 1 0 0   <transform, which calculates parameter values only>
   <more points not shown>
}
}
member SWEEP "va"   <this Transform is dependent on Input "va">
member OUT "ia"     <this Transform is dependent on Output "ia">
}
```

```
Link PLOT "i_vs_v"  <Plot definition starts here>
{
applic "Display Plot" 0 5 435 <Plot window is closed, but located at pixels 5,435>
applic "Display Data" 0 -1 -1   <data window has never been opened>
subapp "Edit plot Info" 0
subapp "Display Data" 1
data
{
plotsize 11960 8970   <Plot size is 11960x8970 (in 1/100 mm)>
HYPTABLE "Edit plot Info"
{
element "Report Type" "XY GRAPH"
}
HYPTABLE "Edit Plot Def"
{
element "X Data" "va"
element "Y Data 0" "ia"
element "Y Data 1" ""
element "Y Data 2" ""
element "Y Data 3" ""
element "Y Data 4" ""
element "Header" ""
element "Footer" ""
element "X Axis Type" "LINEAR"
element "Y Axis Type" "LINEAR"
element "Y2 Axis Type" "LINEAR"
element "Y2 Data" ""
}
}
member INPUT "va"
member OUT "ia"
}
data <data section for Setup - instrument options table information>
{
TABLE "HP4141.7.23"   <HP4141 DC parameter measurement instrument>
{
element 0 "Use User Sweep" "No"
element 0 "Hold Time[0-650s]" " 0.000 "
element 0 "Delay Time[0-6.5s]" " 0.000 "
element 0 "Integ Time" "S"
} TABLE "HP4275.7.10"
{
element 0 "Hold Time[0-650]" " 0.000 "
element 0 "Delay Time[0-650]" " 0.000 "
element 0 "High Res" "No"
element 0 "Meas Freq (KHz)" "10"
}
}
}
}
}   <end of complete Model file>
```

11 Variables

Several variable names are reserved by IC-CAP and cannot be used for user-defined variables. You can assign values to reserved variables and define your own variables at several different levels:

- Globally
- Model
- DUT
- Setup

These levels can be viewed as a hierarchy where variables at lower levels inherit their values from variables at some level above them.

You define global variables through the IC-CAP/Main window. These variables apply to all Models, DUTs, and Setups unless you explicitly set the variables differently at the Model, DUT, or Setup level.

You define Model, DUT, and Setup variables through the Model window:

- Model variables apply to all DUTs and Setups of that Model unless you explicitly set the variables differently for individual DUTs and/or Setups.
- DUT variables apply to all Setups of that DUT unless you explicitly set the variables differently for individual Setups.
- Setup variables apply only to that Setup.

CAUTION The maximum string length for a variable table is 15 K characters. Exceeding this limit may cause a core file to be generated when saving or reading a file.

Table 75 Plot Characteristics

Variable	Description
ANNOTATE_AUTO	Sets a flag to enable or disable automatic annotation update upon data changes. Default is No.
ANNOTATE_CSET	Sets a *Starbase* character set to be used for annotation texts. Default value is determined by */usr/lib/starbase/defaults.*
ANNOTATE_FILE	Sets a file name from which a plot reads in an annotation text. Default is no file to read.
ANNOTATE_MACRO	Sets a macro name that is executed by a Plot for generating an annotation text. Default is no macro to execute.
ANNOTATE_PLOTS	Obsolete in IC-CAP 2006. Now to enable or disable annotation on a plot, use the Plot Options dialog box. See "Setting Plot Options" in the *User's Guide*.
CDF_ERROR_FIT	Can be set to TRUE or FALSE. TRUE will draw the Gaussian curve fitted to the Cumulative plot. Default is TRUE.
CHECK_PLOT_MATCH	Lets IC-CAP check if a given XY pair belongs to the same Setup. If No, potentially mismatched XY pair can be shown in a tabular format with Display Data. Default is Yes.
DASH_DOT	Sets the number of data points at which a simulated line changes from a dashed to a dotted line. Used in Plot. Default value is 32.
DYNAMIC_MULTIPLOT_MODE	Sets the location where the manual scaling setting is saved for a Multiplot. If set to FALSE, the manual scaling setting for each subplot in a Multiplot is saved with the Multiplot, allowing different scaling to be saved for the same plot if opened as a single plot or on one or more Multiplot. If set to TRUE, the manual scaling setting for each subplot in a Mulitplot is saved with the subplot. In this mode, no matter where the plot is opened (as a single plot or on one or more Multiplots), it will use the same scaling information. However, if the same subplot appears on multiple Multiplots, or in multiple positions of the same Multiplot, then the settings for only the last subplot closed is saved. Default is FALSE.

Table 75 Plot Characteristics (continued)

Variable	Description
FIX_PLOT_SIZE	If Yes, Plot windows open using the size specified by GWINDX and GWINDY. If No, they open using the last displayed size. Default is No.
GWIND_WHITE	Obsolete in IC-CAP 2006. Now to set the background color of plots, use the Plot Options dialog box. See "Setting Plot Options" in the *User's Guide*.
GWINDX	Sets the initial Plot window horizontal size in 1/100mm. Used in Plot. Default value is 12500.
GWINDY	Sets the initial Plot window vertical size in 1/100mm. Used in Plot. Default value is 9000.
HISTOGRAM_NUM_BINS	Number of bins in the histogram plot. Default is 10.
HISTOGRAM_NORMALIZATION	Can be set to either TRUE or FALSE. Setting it to TRUE will normalize the histogram. Default is TRUE.
HISTOGRAM_GAUSSIAN_FIT	Can be set to either TRUE or FALSE. Setting it to TRUE will draw the Gaussian curve fitted to the histogram. Default is TRUE.
IGNORE_PLOT_LOC	If Yes, Plot windows open using the X windows system configuration. If No, they open using the last displayed location. Default is No.
MINLOG	Can be set to a real value. Defines the value to be used in a LOG plot, if data point value is zero or negative. Default is 10e-18.
OFFSCREEN_PLOT_LINE_WIDTH	Same as PLOT_LINE_WIDTH, except has no effect when the plot is drawn to the screen. It does have effect when plotting to a file or sending to a printer.
OFFSCREEN_PLOT_TRACE_LINE_WIDTH	Same as PLOT_TRACE_LINE_WIDTH, except has no effect when the plot is drawn to the screen. It does have effect when plotting to a file or sending to a printer.
PLOT_LINE_WIDTH	Sets the line thickness used when drawing a plot grid and annotation. Note: use PLOT_TRACE_LINE_WIDTH to set trace widths on a plot. Default is 1.
PLOT_TRACE_LINE	Sets whether trace line is drawn or not. If defined as Yes, the trace lines are drawn. If defined as No, the trace lines will not be drawn, and instead markers will be drawn. Default is Yes.
PLOT_TRACE_LINE_WIDTH	Sets the line thickness used when drawing the traces of a plot. Note: use PLOT_TRACE_LINE to set line thickness for grid and annotation. Default is 1.
RETAIN_PLOT	When Yes and Auto Scale is off, plot is not erased when updated to allow overlay of curves if the X server has *backing store* capability. Default is No.

Table 75 Plot Characteristics (continued)

Variable	Description
RI_GRAPH_SYMMETRY	When defined as Yes, the plot title is displayed. If defined as No, the plot title is not displayed. Default is Yes.
SCATTER_CONTOURS	Can be set to either TRUE or FALSE. Setting it to TRUE will draw the contours. Default is TRUE.
SCATTER_NUM_SEGMENTS	The number of segments with which to draw the contours. Default is 1500.
SHOW_GRID	When No, plot eliminates XY grids and leaves tics. Default is Yes.
SHOW_PLOT_TITLE	Obsolete in IC-CAP 2006. Now to show or hide the plot title, use the Plot Options dialog box. See "Setting Plot Options" in the *User's Guide*.
USE_PLOT_LOOKUP	Lets IC-CAP perform auto-lookup of X data from each Y data. Another way to disable auto-lookup is to use an arbitrary expression for an X data. Default is Yes.

Table 76 Plot Optimizer

Variable	Description

AUTOSET_COEFF	Sets the coefficient value used to calculate the Plot Optimizer's Min and Max parameter values. Min and Max parameter values are calculated as follows:
	if (value > 0)
	Min = value/coeff
	Max = value × coeff
	if (value < 0)
	Min = value × coeff
	Max = value/coeff
	if (value ==0)
	Min = -coeff
	Max = +coeff
	Default is 5.

OPT_PARTABLE_SHOW_MODEL_ONLY	If set to Yes, displays the model parameters in the parameter list shown in the parameter table tab of Plot Optimizer and normal Optimizer transforms. If set to No, displays all the model and DUT parameters found in the enable plots paths. Default is Yes for the Plot Optimizer and No for the Extract/Optimize folder.

Table 76 Plot Optimizer (continued)

Variable	Description
OPT_PARTABLE_SHOW_PARS	If set to Yes, displays all parameters, except model parameters, in the parameter list in the Plot Optimizer and Extract/Optimize folder. If set to No, hides the parameters. Default is Yes.
OPT_PARTABLE_SHOW_VARS	If set to Yes, displays all variables in the parameter list in the Plot Optimizer and Extract/Optimize folder. If set to No, hides the variables. Default is Yes.
PLOTOPT_USE_YAXES_TYPE	Sets whether the Plot Optimizer algorithm can use the LOG10() and DB() functions to insert the trace equations into the Plot Optimizer. If defined as Yes (Default), the Plot Optimizer algorithm uses the LOG10() function when the Y Axis Type is LOG10 and the DB() function when the Y Axis Type is DB. If defined as No, the Plot Optimizer algorithm does not use the LOG10() and DB() functions regardless of the Axis Type. Default is Yes.
PLOTOPT_AUTOCONFIG_WARNING	Sets whether autoconfigure issues a warning to the Status window when one or more traces could not be autoconfigured. If defined as Yes (Default), a warning is issued when one or more traces could not be autoconfigured. If defined as No, no warning is issued when autoconfigure fails. Default is Yes.

Table 77 Calibration

Variable	Description
CAL_OPEN_C	Obsoleted and replaced by *CAL_OPEN_C0*.
CAL_OPEN_C0 CAL_OPEN_C1 CAL_OPEN_C2	Sets the open capacitance of an Open standard in farads that is used with Software Calibration. The combined value Copen applies to both port 1 and 2. A second-order polynomial represents its frequency dependence. Default value is 0. Copen = C0 + C1 * F + C2 * F^2
CAL_Z0	Obsoleted and replaced by *TWOPORT_Z0*.

Table 78 UI Options

Variable	Description
DUT_TREE_COLS	Controls the width of the tree list in the DUTs-Setups folder. The variable controls the folder in the scope of the variable table where it is defined. The variable's value sets the list's width in number of columns.
MACRO_LIST_COLS	Controls the width of the Select Macro list in the Macros folder. The variable controls the folder in the scope of the variable table where it is defined. The variable's value sets the list's width in number of columns.
MAXIMUM_LIST_LENGTH	The maximum number of value fields allowed for an input where LIST is the Sweep Type and a variable is used to specify '# of Values.' If a constant is used to specify '# of Values,' MAXIMUM_LIST_LENGTH is ignored. Default is 15.
MEAS_SIM_LIST_COLS	Controls the width of the Input/Output Finder list in the Measure/Simulate folder. The variable, SHOW_INPUT_OUTPUT_FINDER, must be enabled to control the list width. The variable controls the folder in the scope of the variable table where it is defined. The variable's value sets the list's width in number of columns.
PARAMETER_PRECISION	Specifies the number of digits used when displaying parameter values in the Parameters table and when sending the values to a simulator. Default is 4.
PLOT_LIST_COLS	Controls the width of the Plot Finder list in the Plots folder. The variable controls the folder in the scope of the variable table where it is defined. The variable's value sets the list's width in number of columns.
RETAIN_DATA	When Yes, data from a Setup is retained if a sweep limit changes but the number of points remains the same. Default is No, which causes the data to be zeroed.
RETAIN_SIMU	A simulator run in piped mode is normally stopped if a new simulator is selected. If Yes, the old simulator is kept running, which will speed up simulations if there is frequent switching between simulators. Default is No.
SHOW_INPUT_OUTPUT_FINDER	When Yes, enables the Input/Output Finder list in the Measure/Simulate folder. If you enable this variable or change its value after viewing the folder, you must close, then re-open the model for the change to take effect. Default is No.

Table 78 UI Options (continued)

Variable	Description
WORKING_PRECISION	Controls the precision of numeric values when converted to text. This precision setting affects only those parts of a model for which the variable is defined. Although all math in IC-CAP is performed using double precision, precision may be lost when a number is converted to text. This conversion occurs in the following situations: any time the function val$() is called; the PRINT statement is used; a numeric value is assigned to a variable in the IC-CAP Variable Table. Because all variables in the IC-CAP Variable Table are text by definition, assigning a numeric value to such a variable will implicitly call val$(). Range of values: 6 through 29. Default is 6. Note: While settings above 17 are allowed, they seldom show any affect.
XFORM_LIST_COLS	Controls the width of the Select Transform list in the Extract/Optimize folder. The variable controls the folder in the scope of the variable table where it is defined. The variable's value sets the list's width in number of columns
GUI_PAGE_SUPRESS_SUMMARY	Normally, IC-CAP displays a short summary of each GUI Item on the GUI Items pages. To suppress this summary and display only the item name (for a cleaner look to the page), set this variable to anything but 0, F, FALSE, N, NO, or blank.

Table 79 PEL

Variable	Description
ICCAP_MAXIMUM_CALL_CHAIN	Sets the maximum number of transforms/macros (written in PEL) that can be called (via *iccap_func()*) without returning. This limit may be set to protect automations under development from infinitely recurring by accident. Without this limit, such infinite recursions will cause IC-CAP to consume all the memory available in your system and then crash. The default value is 0 which means to permit any number of calls.

Table 80 Measurement Options

Variable	Description
8510_MAXFREQ	The 8510 driver checks that the maximum frequency of the instrument is not exceeded. Use this variable to override the built-in value and specify the desired maximum frequency to be checked.
BYPASS_CV_CAL	When set to NO (Default), CV measurements using an HP/Agilent 42XX CV or LCR Meter will request user to calibrate the instrument. After a successful calibration, this step is bypassed on all subsequent measurements. If set to YES, the calibration step is *always* bypassed. CAUTION: Setting variable to YES assumes the instrument has already been calibrated. Use YES for measurement automation.
CV_FREQ	Sets the frequency in Hz at which CV simulation is performed. Default value is 1MEG (Hz).
HPIB_READ_STRING	Gets the results of a Read String operation in the GPIB Analyzer.
IGNORE_8510_RF_UNLOCK	When defined as Yes IC-CAP ignores a temporary and benign RF UNLOCK error from the 8510.
INST_START_ADDR	Specifies the start address for instrument searching during Rebuild (active list). This value should be an integer between 0 and 31, inclusively. When there is a printer, plotter, or prober on the same GPIB with measurement instruments, set INST_START_ADDR greater than any one of those non-instruments to avoid the identification process. Default is 0.
INST_END_ADDR	Specifies the ending address for instrument searching during Rebuild (active list). This value should be greater than the INST_START_ADDR value and less than 31.
LCR_RST_MEM LCR_RST_MEM_<unit>	Sets the reset instrument state for the 4284, 4285, and E4980A instruments. To specify a particular unit, set LCR_RST_MEM_<unit> (e.g., LCR_RST_MEM_CM). IC-CAP drivers reset instruments to known states prior to configuring them for the current measurement. The 4284, 4284, and E4980 send the *RST command, which resets the instruments to a known factory state. However, this default state (1V, 1KHz signal) may cause damage to certain devices between the time the $RST is requested and the time the requested signal level is set. If LCR_RST_MEM or LCR_RST_MEM_<unit> is set, the 4284, 4285, and E4980A instruments will use the value of the variable to set the instrument state. For example, if set to 1, the driver will recall instrument state 1 instead of *RST. For additional information, see the example model file in misc/prepare_CV_Meter.mdl.
MAX_SETUP_POINTS	Specifies the maximum number of points to be permitted within a setup. Default value is 50000.

Table 80 Measurement Options (continued)

Variable	Description
MDS_MEASURE_FAST	Flag reserved for use by the HPRoot model extraction in the High-Frequency IC-CAP software. Default is No.
MEASURE_FAST	When Yes, IC-CAP will attempt to minimize instrument re-initialization during repeated measurements on the same Setup. Refer to *Speeding Up Repetitive Measurements* in the *Measurement* chapter. Default is No.
NO_ZEROING	When Yes, IC-CAP will avoid a preliminary step of zeroing DC and other signal sources at the beginning of measurements. Refer to MEASURE_FAST. Default is No.
PARALLEL_INPUT_UNITS_OK	Overrides a warning when multiple units share a single input node. Default value is No, to issue a warning.
PRE_5_8510_FIRMWARE	For HP 8510B Network Analyzers with firmware revisions prior to HP8510B.05.00: Dec 5, 1988 only. Declaring this variable prevents certain commands (DETENORB--set detector to normal bandwidth, and EXTTOFF--external triggr off) from being sent to the NWA. These commands are not supported in the above-referenced firmware and sending such commands causes a measurement failure. Declare this variable to prevent the failure. No value assignment required.
8510_MAXFREQ	The 8510 driver checks that the maximum frequency of the instrument is not exceeded. Use this variable to override the built-in value and specify desired maximum frequency to be checked.

Table 81 HP85124 Measurement Options

Variable	Description
These variables are used to modify the source tuning process. Source tuning is specified with an entry in the options table. Source tuning process varies the supply voltage to compensate for I*R drop in getting to the device under test.	
p1_step_size	Type = REAL, Default = 0.0 This variable sets a fixed step size for newton iterations when tuning the source voltage for port 1. Default is an auto step size, determined from dvm noise floor.

Table 81 HP85124 Measurement Options

Variable	Description
p2_step_size	Type = REAL, Default = 0.0 This variable sets a fixed step size for newton iterations when tuning the source voltage for port 2. Default is an auto step size, determined from dvm noise floor.
p1_step_scale	Type = REAL, Default = 1.0 This variable sets a scale factor to modify the auto step size in newton iterations when tuning the source voltage for port 1. The auto step size is multiplied by this value.
p2_step_scale	Type = REAL, Default = 1.0 This variable sets a scale factor to modify the auto step size in newton iterations when tuning the source voltage for port 2. The auto step size is multiplied by this value.
p1_tune_error	Type = REAL, Default = 0.0 This variable sets a fixed error goal for tuning the source voltage for port 1 instead of the default auto ranged error which is determined from the dvm noise floor.
p2_tune_error	Type = REAL, Default = 0.0 This variable sets a fixed error goal for tuning the source voltage for port 2 instead of the default auto ranged error which is determined from the dvm noise floor.
p1_error_scale	Type = REAL, Default = 1.0 This variable sets a scale factor to modify the auto ranged error goal for tuning the source voltage for port 1 The auto ranged error goal is multiplied by this value.
p2_error_scale	Type = REAL, Default = 1.0 This variable sets a scale factor to modify the auto ranged error goal for tuning the source voltage for port 2 The auto ranged error goal is multiplied by this value.
max_newton_iters	Type = INT, Default = 6 This variable sets the maximum number of newton iterations to complete before quitting the source tuning process.
pulse_rise_time	Type = REAL, Default = 0.2E-6 This variable specifies the average rise time for the pulse. This is used in determining if the measurement delay results in a measurement in the pulse. If the measurement for source tuning is not in the pulse then the resulting voltage will be very high.
pulse_fall_time	Type = REAL, Default = 0.2E-6 This variable specifies the average fall time for the pulse. This is used in determining if the measurement delay results in a measurement in the pulse. If the measurement for source tuning is not in the pulse then the resulting voltage will be very high.
These variables can be used to initiate printing of data to the status window. This data is useful in troubleshooting measurement problems and data accuracy questions.	

Table 81 HP85124 Measurement Options

Variable	Description
show_tuning	Type = INT, Default = 0, Values 0 or 1 When set to 1 measured values, tuning error, and next value to be tries are displayed for the source tuning process. These values are printed the status window.
show_samples	Type = INT, Default = 0, Values 0 or 1 When set to 1 all the dvm or adc measurements are displayed in the status window.
show_stats	Type = INT, Default = 0, Values 0 or 1 When set to 1 statistical information about the measured data is displayed. Data includes mean , min, and max. Data is displayed in the status window.
show_current_range	Type = INT, Default = 0, Values 0 or 1 When set to 1 the present current range is displayed to the status window when the measurement begins and any time the range changes.
show_voltage_range	Type = INT, Default = 0, Values 0 or 1 When set to 1 the present voltage range is displayed to the status window when the measurement begins and any time the range changes.
These variables are used to over-ride the offsets defined in the hp85124.cal file.	
p1_meas_offset	Type = REAL, Default = value in hp85124.cal This variable will over-ride the input_measurement_offset variable in the hp85124.cal file. This variable adjusts the delay for the port 1 voltage measurement.
p2_meas_offset	Type = REAL, Default = value in hp85124.cal This variable will over-ride the output_measurement_offset variable in the hp85124.cal file. This variable adjusts the delay for the port 2 voltage measurement.
p1_meas_i_offset	Type = REAL, Default = value in hp85124.cal This variable will over-ride the input_current_measurement_offset variable in the hp85124.cal file. This variable adjusts the delay for the port 1 current measurement. This offset is relative the voltage measurement.
p2_meas_i_offset	Type = REAL, Default = value in hp85124.cal This variable will over-ride the output_current_measurement_offset variable in the hp85124.cal file. This variable adjusts the delay for the port 2 current measurement. This offset is relative the voltage measurement.
These variables are used to over-ride the instrument types specified in the hp85124.cfg file.	
p1_v_type	Type = STRING, Default = value in hp85124.cfg This variable over-rides the value of dmm_vin in the hp85124.cfg file. This will also over-ride the automatic change for risetime mode. The default is to use the hp3458 dvm for slow mode and the internal adc (K49 only) for fast mode.

Table 81 HP85124 Measurement Options

Variable	Description
p1_i_type	Type = STRING, Default = value in hp85124.cfg This variable over-rides the value of dmm_iin in the hp85124.cfg file. This will also over-ride the automatic change for risetime mode. The default is to use the hp3458 dvm for slow mode and the internal adc (K49 only) for fast mode.
p2_v_type	Type = STRING, Default = value in hp85124.cfg This variable over-rides the value of dmm_vout in the hp85124.cfg file. This will also over-ride the automatic change for risetime mode. The default is to use the hp3458 dvm for slow mode and the internal adc (K49 only) for fast mode.
p2_i_type	Type = STRING, Default = value in hp85124.cfg This variable over-rides the value of dmm_iout in the hp85124.cfg file. This will also over-ride the automatic change for risetime mode. The default is to use the hp3458 dvm for slow mode and the internal adc (K49 only) for fast mode.
These variables are used to make changes in the default settings used for the hp3458 dmms	
dvm_terminals	Type = CHAR, Default = R, Values = R or F This variable will change which set of terminals the dmm will read. The choice is R for rear and F for front.
dvm_trigger_mode	Type = CHAR, Default = E, Values = E or I This variable will change the trigger mode of the dmm. E for external and I for internal.
dvm_aperture	Type = REAL, Default = 1E-6 This variable changes the value of the aperture for DCV mode of the dmms.
dvm_track_hold	Type = INT, Default = 1, Values 0 or 1 This variable sets either track and hold mode (DSDC) or integrated mode (DCV).
dvm_auto_zero	Type = STRING, Default = ONCE, Values = OFF, ON, or ONCE This variable sets the auto zero mode on the dmms.
allow_internal	Type = INT , Default = 0, Values = 1/0 This variable allows the dmm to take more samplings within the same pulse during time domain pulse profile measurements if the time interval is less than 20us.

Table 82 General Extraction Options

Variable	Description
EXTR_DUT	Used internally in extractions. When a circuit or test circuit has been defined, set this variable to the name of the DUT whose parameters are either extracted or used by the IC-CAP device extraction functions.
EXTR_MODEL	Used internally in extractions. When a circuit has been defined, set this variable to the name of the model whose parameters are either extracted or used by the IC-CAP device extraction functions.
POLARITY	Specifies the device polarity of the device to be extracted. Allowed values for bipolar devices are NPN or PNP. Default is NPN for bipolar devices. Allowed values for MOS devices are NMOS or PMOS. Default is NMOS for MOS devices.
WORKING_PRECISION	Controls the precision of numeric values when converted to text. This precision setting affects only those parts of a model for which the variable is defined. (Converting to text is done when: the function val$() is called; the PRINT statement is used; a numeric value is assigned to a variable in the IC-CAP Variable Table.) Range of values: 6 and higher. Default is 6. Note: While settings above 17 are allowed, a double precision number cannot be expressed to this precision.

Table 83 General Simulation Options

Variable	Description
DEFAULT_SIMU	Sets the default simulator name. Used in Utilities.
MAX_DC_SWEEPS	Specifies the maximum number of DC sweeps for a simulation. Default is simulator-dependent.
MAX_SETUP_POINTS	Specifies the maximum number of points to be permitted within a setup. Default value is 50000.
OPEN_RES	Specifies the resistance value that is automatically connected to all floating nodes in the circuit. This is available for all simulators with links to IC-CAP. When this variable is not specified, a zero amp current source is connected to the node.
PARAMETER_PRECISION	Specifies the number of digits used when displaying parameter values in the Parameters table and when sending the values to a simulator. Default is 4.

Table 83 General Simulation Options (continued)

Variable	Description
SIMULATOR	Specifies the simulator name to be used in all simulations performed under the level in which this variable is defined. The name must be a valid simulator; otherwise, the currently selected simulator is used. Default is the currently selected simulator.
SIM_USE_UPPER_CASE_PARAMS	By default parameters are entered into the Parameters table with the same capitalization as entered in the circuit page. (The hpeesofsim simulator is an exception.) If set to 'F', 'N', 'FALSE','No' or '0' the default behavior will result. Any other setting will force the parameters in the Parameters table to be represented in upper case according to the following rules: • If the parameter was declared with $dpar, $mpar, or $xpar, capitalization is not affected. • If the parameter contains a period, only the part of the parameter after the last period is upper case. • If the parameter does not contain a period, the entire parameter is upper case. If USE_OLD_CASE_PARM_RULE is set to anything other than 'F', 'N', 'FALSE','No' or '0' (case insensitive), this setting follows different rules. See USE_OLD_CASE_PARM_RULE. This setting affects all simulators but may be overridden by HPEESOFSIM_USE_LOWER_CASE_PARAMS and HPEESOFSIM_USE_MIXED_CASE_PARAMS for the hpeesofsim simulator.
SIM_USE_LOWER_CASE_PARAMS	By default parameters are entered into the Parameters table with the same capitalization as entered in the circuit page. (The hpeesofsim simulator is an exception.) If set to 'F', 'N', 'FALSE','No' or '0' the default behavior will result. Any other setting will force the parameters in the Parameters table to be represented in lower case according to the following rules: • If the parameter was declared with $dpar, $mpar, or $xpar, capitalization is not affected. • If the parameter contains a period, only the part of the parameter after the last period is lower case. • If the parameter does not contain a period, the entire parameter is lower case. If USE_OLD_CASE_PARM_RULE is set to anything other than 'F', 'N', 'FALSE','No' or '0' (case insensitive), this setting follows different rules. See USE_OLD_CASE_PARM_RULE. This setting affects all simulators but may be overridden by HPEESOFSIM_USE_LOWER_CASE_PARAMS and HPEESOFSIM_USE_MIXED_CASE_PARAMS for the hpeesofsim simulator.

Table 83 General Simulation Options (continued)

Variable	Description
TEMP	Temperature at which simulations are performed. When performing an optimization to extract model parameters, TEMP and TNOM should be set to the same value so that simulations during optimization are performed at TNOM. Default value is simulator-dependent.
TNOM	Temperature at which the model parameters are extracted. TNOM must be defined in order to guarantee consistency between simulation and extraction. Default value is 27 when performing an extraction, and is simulator dependent when performing a simulation.
TWOPORT_C	Sets a DC decouple capacitance value when a 2-port circuit is generated from a circuit for 2-port simulation. Default is 100 farad.
TWOPORT_L	Sets an AC decouple inductance value when a 2-port circuit is generated from a circuit for 2-port simulation. Default is 100 henry.
TWOPORT_Z0	Sets a characteristic impedance value for 2-port circuit that is used in AC extractions, TwoPort function, and Software calibration. Default is 50 ohm.
USE_OLD_CASE_PARM_RULE	If set to anything other than 'F', 'N', 'FALSE','No' or '0' (case insensitive), this setting changes the rules for SIM_USE_UPPER_CASE_PARAMS, SIM_USE_LOWER_CASE_PARAMS, HPEESOFSIM_USE_LOWER_CASE_PARAMS, and HPEESOFSIM_USE_MIXED_CASE_PARAMS to the following: • If the parameter was declared with $dpar, $mpar, or $xpar, the case is changed for the entire parameter name according to the case variable. • If the parameter contains a period, only the part of the parameter after the last period is changed according to the case variable. • If the parameter does not contain a period and the parameter is named for an instance, the case is unchanged. • If the parameter does not contain a period and the parameter is named for a parameter on a model, the case is changed according to the case variable. For example, *rtest 1 2 50* Parameter *rtest* is named for the instance in SPICE, so case is not changed according to the case variable. *model x NPN alpha=4* Parameter *alpha* is named for a model parameter, so case is changed according to the case variable.

NOTE

When using the ADS simulator (hpeesofsim), there is no way to set the temperature just for Noise analysis. Therefore, the analysis will be done at the circuit temperature.

Table 84 hpeesofsim Options

Variable	Description
BANDWIDTH	Bandwidth for noise analysis. Default = 1 Hz.
HPEESOFSIM_HB_OPTIONS	A string that contains the analysis options used in an ADS Harmonic Balance simulation. No default.
HPEESOFSIM_OPTIONS	A string which contains the analysis options used in an hpeesofsim simulation. No default.
HPEESOFSIM_TRAN_OPTIONS	A string that contains the analysis options used in an ADS Transient simulation. No default.
HPEESOFSIM_USE_LOWER_CASE_PARAMS	This setting affects only the hpeesofsim simulator. By default parameters are converted to all uppercase. If set to 'F', 'N', 'FALSE','No' or '0' the default behavior will result. Any other setting will force the parameters in the Parameters table to be represented in lower case according to the following rules: • If the parameter was declared with $dpar, $mpar, or $xpar, capitalization is not affected. • If the parameter contains a period, only the part of the parameter after the last period is lower case. • If the parameter does not contain a period, the entire parameter is lower case. If USE_OLD_CASE_PARM_RULE is set to anything other than 'F', 'N', 'FALSE','No' or '0' (case insensitive), this setting follows different rules. See USE_OLD_CASE_PARM_RULE.

Table 84 hpeesofsim Options

Variable	Description
HPEESOFSIM_USE_MIXED_CASE_PARAMS	This setting affects only the hpeesofsim simulator. By default parameters are converted to all uppercase. If set to 'F', 'N', 'FALSE','No' or '0' the default behavior will result. Any other setting will force the parameters in the Parameters table to be represented with the same case as they appear in the Circuit page according to the following rules: • If the parameter was declared with $dpar, $mpar, or $xpar, capitalization is not affected. • If the parameter contains a period, only the part of the parameter after the last period is the same case as they appear in the Circuit page. • If the parameter does not contain a period, the entire parameter is the same case as they appear in the Circuit page. If USE_OLD_CASE_PARM_RULE is set to anything other than 'F', 'N', 'FALSE','No' or '0' (case insensitive), this setting follows different rules. See USE_OLD_CASE_PARM_RULE.
INCLUDEPORTNOISE	Includes the port noise in noise voltage and currents. Default = Yes.
NOISETEMP	Circuit temperature (Kelvin) for noise analysis. Default = 290.
MAX_PARALLEL_SIMULATOR	Specifies the maximum number of simultaneous hpeesofsim simulators that can be run. Default value is 3.

Table 85 MNS Options

Variable	Description
BANDWIDTH	Bandwidth for noise analysis. Default = 1 Hz.
INCLUDEPORTNOISE	Includes the port noise in noise voltage and currents. Default = Yes.
MNS_OPTIONS	String that contains the analysis options used in an MNS simulation. No default.
MNS_HB_OPTIONS	A string that contains the analysis options used in an MNS Harmonic Balance simulation. No default.
MNS_TRAN_OPTIONS	A string that contains the analysis options used in an MNS Transient simulation. No default.
NOISETEMP	Circuit temperature (Kelvin) for noise analysis. Default = 290.

Table 86 Mextram Extraction Options

Variable	Description
MXT_AUTO_RANGE	Type = INT , Default = 0, Values = 1/0 This variable selects auto range capabilities for MEXTRAM parameter extraction. It is usually defined at model or setup level
MXT_AUTO_SMOOTH	Type = INT , Default = 0, Values = 1/0 This variable select smoothing on the measured data before applying the auto range algorithms during MEXTRAM parameter extraction. It is usually not required unless the data is rather noisy. It is usually defined at model or setup level.

Table 87 ELDO Options

Variable	Description
ELDO_VERSION	Specifies the version of ELDO being used in the simulation. This information is necessary because the syntax used to call ELDO depends on the version number. If this variable is not specified, IC-CAP will use the version specified in the environment variable eldover, if it exists. Default is v4.2.1.

Table 88 Saber Options

Variable	Description
SABER_ALTER	A command string that appears in the Saber command file to modify simulation-related variables in Saber. Multiple commands are separated by semi-colon.
SABER_DC_OPTIONS	String that contains the DC operating point options used in a SABER simulation. Multiple options are separated by commas.
SABER_OPTIONS	String that contains the analysis options used in a SABER simulation. Multiple options are separated by commas.
USE_ALTER	Specifies whether or not the alter command should be used in a SABER simulation. Default is Yes.
SABER_VERSION	Specifies the version of SABER being used in the simulation. This information is needed if you are using a version earlier than 4.3 (syntax for DC log sweeps is different) or 5.0 (output files have different names). Default is 5.0.
USE_DCIP_COM	Specifies whether or not the dcip and dcep commands should be used in a SABER simulation to speed up LIST and LOG sweeps. Valid entries are Yes and No. Default is Yes.

Table 88 Saber Options

Variable	Description
USE_SABER_COM	Specifies whether or not the 'saber' command to load a new netlist without restarting the simulator should be used in a SABER simulation. Valid entries are Yes and No. Default is No.

Table 89 HSPICE Options

Variable	Description
HSPICE_NODE_STRLEN	When netlisting the sources and analysis statements for HSPICE simulations, node names are truncated to 3 characters by default. You can control the number of characters for node names by setting HSPICE_NODE_STRLEN to 3, 4, 5, 6, or 7. If you set the value to less than 3, the minumin value of 3 will be used. If you set the value to larger than 7, the maximum value of 7 will be used.
HSPICE_VERSION	Specifies the version of HSPICE being used in the simulation. Default is h93a. Other possible values are h92 and h9007.

Table 90 Print/Plot Options

Variable	Description
DRIVER	Obsolete
DUMP_CMND	Sets the graphics dump command to a printer. Used in Plots. Default value on HP is *pcltrans -e3 | lp -oraw*, and is *xpr -device ps | lpr* on Sun.
DUMP_DPI	Obsolete
DUMP_WHITE	Obsolete
PAPER	Sets paper size as either A4 or A3 for graphics output. Used in Plot. Default value is A4, which is also good for US letter size.
PLOT_CMND	Sets the HPGL plotting command. Default value on HP is cat > HPGL, and is not applicable on Sun.
PLOT_SCALE_FACTOR	Sets the scale factor used in conjunction with iccap_func *Dump Via Server*. Default value is 1.0.
PRINT_CMND	Sets the text output command to a printer. Used in several windows. Default is lp.

Table 91 Factory Diagnostics

Variable	Description
IC_DIAG_FLAGS	Reserved for factory diagnostics.

Table 92 Curtice Extraction Options

Variable	Description
CONSTANT_TAU	When Yes, the AC extraction will extract the internal time delay in the Curtice GaAs MESFET represented by the model parameter TAU. This model parameter forces the model to use a constant delay time. When not defined the parameter A5 is extracted that represents a variable time delay as a function of VDS. Default is No.
LINEAR_CGD	When Yes, the AC extraction for the Curtice GaAs MESFET will extract a value for a linear gate-to-drain capacitance represented by the model parameter CGD. When not defined the only capacitance extracted is the non-linear junction capacitance CGDO. Default is No.
LINEAR_CGS	When Yes, the AC extraction for the Curtice GaAs MESFET will extract a value for a linear gate-to-source capacitance represented by the model parameter CGS. When not defined the only capacitance extracted is the non-linear junction capacitance CGSO. Default is No.

Table 93 BJT High Freq Extraction Options

Variable	Description
SCALEITF	ITF multiplier for the decoupled extraction in the *BJTAC_high_freq* extraction function. The decoupled extraction is called when the coupled extraction fails. Default value is 1.0.
SCALETF	TF multiplier for the decoupled extraction in the *BJTAC_high_freq* extraction function. The decoupled extraction is called when the coupled extraction fails. Default value is 1.0.
SCALEVTF	VTF multiplier for the decoupled extraction in the *BJTAC_high_freq* extraction function. The decoupled extraction is called when the coupled extraction fails. Default value is 1.0.
SCALEXTF	XTF multiplier for the decoupled extraction in the *BJTAC_high_freq* extraction function. The decoupled extraction is called when the coupled extraction fails. Default value is 1.0.
MAXRB	Specifies the maximum value of the RB and RBM parameters for the extraction. Default is 5K.

Table 94 UCB MOS Extraction Options

Variable	Description
WD	Used in the UCB MOSFET LEVEL 2 and 3 model characterizations to represent the channel width reduction parameter. This parameter is not defined in the UCB models but has been added to many proprietary versions of the models. Default is 0.

Table 95 X_HIGH/Y_HIGH Options

Variable	Description
OVERRIDE_LIMITS	When Yes, user can manually specify limits for certain bipolar and GaAs extractions with the X_LOW and X_HIGH variables. Default is No.
X_HIGH, X_LOW	Plots can interactively set these values to the X values of a rescale rectangle.
Y_HIGH, Y_LOW	Plots can interactively set these values to the Y values of a rescale rectangle.

Table 96 Data Management Options

Variable	Description
MDM_AUTO_PRECISION	This variable is obsolete in version 5.3. See MDM_REL_ERROR and MDM_ZERO_TOL.
MDM_EXPORT_COMMENT	Specifies the text to be added as comment at the top of the MDM file when exporting data. The text can include an embedded variable as val$(var-name), pre-defined program variables DATE, NEWLINE, TAB, MODEL, DUT, SETUP. Some examples are: MDM_STD_COM - Today's date : $DATE MDM_EXPORT_COMMENT - val$(MDM_STD_COM) MDM_EXPORT_COMMENT - MDM file exported on $DATE MDM_EXPORT_COMMENT - Date: $DATE $SETUP L=val$(L) W=val$(W) where W and L are Model, DUT or Setup parameters/variables.
MDM_EXPORT_COMMENT_FILE	Specifies the Data Manager comment file to be used when exporting data to an MDM file. The contents of the comment file are pre-pended to the MDM file
MDM_EXPORT_XFORM_DATA	Setting this value to TRUE, will export all the transform(s) data (or those transforms specified by MDM_XFORM_LIST) in the setup to the MDM data-file. This variable is automatically set to TRUE when you select the checkbox 'Export Transforms' in the Export Data dialog. Default is FALSE. See MDM_XFORM_LIST.

Table 96 Data Management Options

Variable	Description
MDM_FILE_PATH	Specifies the Data Management file name path.
MDM_FILE_NAME	Specifies the Data Management file name.
MDM_HEADER_VERBOSE	Specifies if the header of the MDM file includes comments describing each field. Default is FALSE.
MDM_PRECISION	This variable is obsolete in version 5.3. See MDM_REL_ERROR and MDM_ZERO_TOL.
MDM_REL_ERROR	When IC-CAP reads values from an MDM file, it tries to match requested input values with data in the MDM. If the data does not exist in the MDM file, importing the data is not advised. However, due to roundoff errors, a tolerance must be assumed. IC-CAP uses the formula MDM_REL_ERROR > (req - mdm)/req as its acceptance test. Default value is 1E-10 This value should rarely need to be adjusted, and can be adjusted for an individual Input. By assigning a value to MDM_REL_ERROR_<*name*> (where <*name*> is the name of the Input to which the tolerance is to be applied), specific control is possible.
MDM_VALUES_LIST	Specifies a space or comma separated list of Parameter or Variable names. The values of these Parameters/Variables are written to the MDM file. When an MDM file with values stored in it is imported or used to auto-create a setup, these Parameters/Variables are automatically reset to the values stored in the MDM. However, if a Parameter or Variable no longer exists in the scope of the setup being imported to, a variable will be created for that value in the Setup Variables Table.

Table 96 Data Management Options

Variable	Description
MDM_XFORM_LIST	Specifies a comma separated list of transform names that will be exported when this setup is exported. By using this variable, you may specify a subset of all transforms for export. In addition you may specify the mode, nodes, and other data. Each transform entry in the comma separated list will appear in the MDM file as an output. The actual values of each output type are shown below: Mode Values ------- ---------- V,N,U <Name> <Mode> <+ Node> <- Node> <Unit> <Type> I <Name> <Mode> <To Node> <From Node> <Unit> <Type> C,G <Name> <Mode> <High Node> <Low Node> <Unit> <Type> T <Name> <Mode> <Node> <Pulse Param> <Unit> <Type> S,H,Z,K,A,Y <Name> <Mode> <Port 1> <Port 2> <AC Ground> <Unit> <Type> Examples: MDM_XFORM_LIST = calc_ic I C E, calc_ib I B E SMU2 MDM_XFORM_LIST = Hcalc H, beta Note, only the transform name is required. You may include as many extra entries per transform as desired. This variable is only referenced if MDM_EXPORT_XFORM_DATA is true. See MDM_EXPORT_XFORM_DATA.
MDM_ZERO_TOL	When IC-CAP reads values from an MDM file, it tries to match requested Input values with data in the MDM. If the data does not exist in the MDM file, importing the data is not advised. However, due to roundoff errors, a tolerance must be assumed. IC-CAP uses the formula MDM_ZERO_TOL > (req - mdm) | req == 0 or mdm == 0 as its acceptance test. Default value is 1E-30. This value should rarely need to be adjusted, and can be adjusted for an individual Inputs. By assigning a value to MDM_ZERO_TOL_<*name*> (where <*name*> is the name of the Input to which the tolerance is to be applied), specific control is possible.

12
GPIB Analyzer

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Macro Files 784

The GPIB analyzer offers basic capabilities for communicating with instruments via the GPIB. It can be used to debug an instrument driver or to manually set an instrument to a certain state not supported by IC-CAP. The analyzer commands are found on the Tools menu in the *Hardware Setup* window; the output is displayed in the Status panel near the bottom of the window.

Menu Commands

Each of the menu items available in the Hardware Setup Window is described in online help.

Macro Files

GPIB analyzer requests can be combined and placed in a macro file that can be executed at any time.

NOTE

IC-CAP macros for IC-CAP Models are different from macro files interpreted by the GPIB analyzer.

The GPIB analyzer's ability to interpret a file containing a series of requests is valuable for:

- Prototyping an instrument driver for testing a series of commands and checking instrument responses. (The GPIB analyzer macro facility includes some capabilities that are not available in interactive use, such as serial polling until a particular bit is set in the response, or delaying for a fixed number of seconds.)
- Repeatedly manually executing a sequence of GPIB analyzer commands.

Macro File Example

This section provides an example of a acceptable GPIB analyzer macro file. The syntax of each line is very simple and the system can readily distinguish comments from commands. Note that expressions, accepted in IC-CAP macros, are not accepted here; most arguments are treated literally. These commands are typed in a text file using any text editor, for example, *vi*.

The Macros submenu (from the Tools menu) provides 2 macro commands: choose *Specify* to provide the name of the file to be read and executed; then, choose *Execute*. If changes are made to the file, it is necessary only to save the changes and again select *Execute*.

```
$c This is a small GPIB Analyzer macro file; this line is a comment
$a 17   active address = 17
$c      send request for instrument ID string:
ID\n
$r      read answer back
$p      print it to the Status window
$c      now send a string to reset the instrument:
RST\n
$w 2    wait 2 seconds after sending RST to instrument
$c      The following '$m' command opens a dialog window, and asks:
$c        'Will now call othermacrofile; want to continue?'
$c      At that point, the user can use the mouse to
$c      cancel the execution of this macro or continue.
$m      Will now call othermacrofile
$i     /users/icuser/othermacrofile   call another macro, like a subroutine
RST\n
$w 2    wait 2 seconds after sending RST to instrument
```

Macro Commands

The macro file contains 2 kinds of statements:

- Literal strings to send to the instruments, such as in the *Send String* command
- Commands and directives, such as *set the active address* or *do a serial poll*.

Commands and directives start with a dollar sign (*$*). Descriptions of the available commands and directives are shown in the following table.

Table 97 Commands and Directives

Command / Directive	Description
$c	Indicates that the current line is purely a comment. Do not attempt to substitute an exclamation mark (!) to indicate a comment.

Table 97 Commands and Directives

Command / Directive	Description
$r	Read data into the GPIB analyzer's read buffer, as in the *Receive String* command. The result is also copied onto the top-level IC-CAP system variable named *HPIB_READ_STRING,* if this variable has been defined by the user.
$a 2	Sets the active address to a literal integer value (2 in this case)
$w 3	Specifies the wait time, in this example, 3 seconds; if the optional argument is absent, a default of 2 is used.
$p	Prints the GPIB analyzer's read buffer, as in the *Display String* command
$m	Displays a message panel for the user to indicate whether to stop or continue. The system appends the phrase want to continue? to the characters that follow $m on the command line. Refer to "Macro File Example" on page 784.
$n	Prints status to the status panel of the Instrument Setup window as the macro is executed, for example: $n the macro has reset the instrument, and is about to download set points
$s	Performs a serial poll of the active address. If an integer parameter is present, then it is considered a serial poll mask, and the program loops until (<poll result> AND <integer mask>) is non-zero, that is, a desired *bit* is set. If the mask is negative, the looping continues until a mask-specified bit is *clear*. For example, to loop until the serial poll response at the active address has a 1 in bit 6, do this: $s 64 To loop until the serial poll response at the active address has a 0 in bit 6, do this: $s -64
$i	Calls or includes another file and execute the macros in it. This is like calling a subroutine; for example, $i /users/icuser/macrofile

Macro File Syntax Rules

The following rules apply when writing GPIB analyzer macro files.

- Macro command files are read by the GPIB bus analyzer and lines in the files elicit GPIB bus analyzer actions. Use only 1 action per line.
- Blank lines, or lines with only white space are ignored. In any line, leading white space is ignored.
- Some lines are sent to the instrument, others are commands or directives.
- If the dollar sign (*$*) appears after optional leading white space, a line is considered a directive or command. Otherwise, the first non-white and all subsequent characters in the line are sent to the active address.
- \b \r \n \0 \f \t \v \\ \$ \<any other single character> will first be converted to control characters or other characters. Use this for sending carriage-return, linefeed, or other terminators. Conversions are listed in the following table. (\<any other single character> is really a no-op; it causes the <any other single character> to be sent. If it is necessary to send a line that starts with the dollar sign, it can be sent by preceding it with a backslash as shown in the following table.)

Table 98 Control Characters in the GPIB analyzer

String in Macro File	Character Sent to Instrument
\b	backspace
\r	CR
\n	newline (linefeed)
\0	null
\f	formfeed
\t	tab
\v	vertical tab

Table 98 Control Characters in the GPIB analyzer

String in Macro File	Character Sent to Instrument
\\	backslash
\$	dollar sign
\<any other single character>	<any other single character>

- Directives and commands have the dollar sign (*$*) character, a single command character that is not case-sensitive, and optional trailing arguments. White space between the command character and the first argument is optional. Recall that any other characters appearing on a line, after the directive and its arguments, are ignored. This allows comments alongside directives if desired. For example,

```
$a 17 this sets the active address to 17
```

  To stay consistent with other facilities in IC-CAP, and to keep GPIB analyzer macro files more readable, you may wish to adopt the following style for end-of-line comments:

```
$a 17 ! this sets the active address to 17
```

  However, do not use the exclamation mark (!) to associate an end-of-line comment to a string sent to an instrument. The ! character and the rest of the comment will be sent to the instrument:

```
RST\n ! OUCH. Not only RST<LF>, but all these other
characters go out also!
```

A
OMI and C++ Glossary

This glossary provides definitions of terminology particular to the programming environment for the Open Measurement Interface and C++. For more information on C++ and its syntax, refer to "Syntax" on page 224.

base class A class from which another class inherits data and functions. For example:

```
// base_class is inherited by derived class
class derived_class : public base_class { ... } ;
// example from user_meas.hxx:
class cvu_4194 : public user_unit { ... } ;
```

Calibrate A menu function to calibrate instruments used by a Setup.

class An extension of struct declarations from C. Like a struct declaration in C, a C++ class declaration can list a series of data members. In addition, a class can declare functions to operate on the data members. When only these functions manipulate the data members, the integrity of the data is better protected. This protection of data members is often termed *encapsulation*. Another important extension beyond struct declarations is the following: a class declaration can automatically contain all the data members from another class, and can reuse all the functions declared in the other class. This capability is termed *inheritance*, and is discussed below. See also *object*.

const Indicates that a function won't change an argument, or acts like #define. For example:

```
// neither char array subject to change below:
int strcmp(const char*, const char*);
// like #define, but without global scope:
const int select_code=7;
```

constructor Function to initialize an object's members. For example, *hp4194::hp4194* in *user_meas.cxx*. Note the special function naming convention, in which the class name appears twice.

dat Class name associated with IC-CAP Setups.

delete A C++ statement used to release memory obtained by *new*.

derive To make a new class that inherits data and functions from a *base class*. In the *base class* example, the class *derived_class* is derived from the class *base_class*.

derived class Opposite of *base class*. A derived class generally adds data and functions beyond what it inherits from its *base class*.

destructor Opposite of *constructor*. Often critical for using *delete* to release memory obtained with *new* during constructor execution. For example, *hp4194::~hp4194* in *user_meas.cxx*. Note the special function naming convention, in which the class name appears twice.

device file A special UNIX file for which reads and writes are done through I/O cards, like a GPIB card. In the OMI, *device file* access (instrument I/O, in other words) is encapsulated within the *hpib_io_port* class.

Driver Generation Scripts refer to *mk_unit*, *mk_instr*, and *mk_instr_ui*.

friend class A class able to access the private members of another class. It is often convenient for an instrument class and its associated unit classes to do this. Examples are presented in "Running the Scripts on Windows" on page 197.

Hardware Manager The single IC-CAP object responsible for the functionality on the main menu of the Hardware Editor.

hpib_io_port A class providing an interface to I/O cards and instruments that supports reading, writing, serial polling, and other functions. Declared in *io_port.h*.

hwmanager Class name associated with *Hardware Manager*.

inherit Obtain data and functions not by declaring them explicitly, but by telling C++ you want the data and functions from another class, in addition to any explicitly declared for a new class. See the example with *base class*, in which *derived_class* inherits *base_class*.

inheritance A C++ feature allowing 1 class to *inherit* the data and functions of another class. This is valuable because a class can reuse existing functionality, while adding to it.

instr[ument] The common *base class* for all instrument objects is *instr* (declared in *instr.h*). See *user_instr.h*.

instr_options Common *base class* for all instrument options editors. See *user_instr_options*.

instrument data Refers to data members declared in the classes *instr*, *user_instr*, *hp4194*, or the instrument class created with the *mk_instr* script.

instrument function Refers to functions declared in the classes *instr*, *user_instr*, *hp4194*, or the instrument class created with the *mk_instr* script.

internal sweep A *main sweep* in which an instrument unit is programmed to acquire a series of data points without IC-CAP directing the acquisition of each individual point. Opposite of *user sweep*.

main sweep The innermost sweep in a measurement. The opposite of a step sweep. In an IC-CAP Input editor, a main sweep has *Sweep Order* set to 1.

Measure A menu function to execute the measurement specified by a Setup.

Measurer The single IC-CAP object with overall responsibility for Measure and Calibrate.

member data The variables declared in a class. When an object is created it gets its own copies of these variables. For example, in *user_meas.hxx*, the class *hp4194* declares a pointer to a *cvu_4194* object as part of the *hp4194*'s member data.

member functions The functions declared in a class. For example, in *user_meas.hxx,* the class *cvu_4194* declares *zero_supply()*.

mk_instr A script to generate declarations for the instrument part of a driver.

mk_instr_ui A script to generate all necessary code for the instrument options editor for a driver.

mk_unit A script to generate declarations for the unit part of a driver.

new A C++ statement that replaces the C malloc function. The *new* statement dynamically allocates memory, and calls a constructor if one is defined. For example:

```
// from hp4194::build_units in user_meas.cxx:
cv_unit = new cvu_4194 (CM,this,1) ;
// array of 1000 double precision numbers:
double* big_array = new double[1000] ;
```

object A data structure containing the variables listed in a class declaration. An object also contains (due to *inheritance*) all the variables declared in any *base class*. An object and its components can be manipulated by the functions in its own class declaration, as well as by the functions in any *base class* declarations.

out Class name associated with IC-CAP Outputs.

overload Give 2 functions the same name, but different argument lists. The compiler distinguishes which one to call by checking the argument lists.

override Declares a function in a derived class, when it was already declared in a *base class*, in order to specialize the behavior of the function for the derived class.

private Used as a keyword in a class declaration to indicate that subsequently declared member data (and sometimes member functions) can only be accessed by the class member functions. *Private* is the default policy in a class declaration, until one of the keywords *protected* or *public* is used.

protected Similar to *private*, though not as strict. It permits *derived* class member functions to have access to the members listed below this keyword.

public Used in 2 senses. First, it is used like *private* but with the opposite effect. It permits any other C++ code to access the members listed below it. Second, it is used in inheritance declarations as follows:

```
class cvu_4194 : public user_unit { ... } ;
```

Although the language permits *public* to be replaced or absent in the declaration above, in OMI programming it should always be present. The role of public in the statement above is explained in such books as Stanley Lippman's *C++ Primer*.

Rebuild Active List A menu function in the Hardware Editor that locates all supported GPIB instruments.

redeclare Same as *override*.

reference argument An argument whose address is passed to a function, to reduce function call overhead, or to permit a called function to directly modify data belonging to the caller. See the explanation for & in *Understanding C++ and its Syntax,* subsection *New Symbols and Operators*.

sweep Class name associated with IC-CAP Inputs. Also a synonym for an IC-CAP Input.

sweep order An integer from 1 or higher. The *main sweep* has sweep order 1. Any step sweeps, if present, have order 2 and higher.

sweep mode The physical dimension associated with a sweep, such as Voltage or Time.

sweep type The type of numerical calculation used to determine the step values in a sweep, such as LIN (linear spacing), or LOG.

unit The common *base class* for all unit objects is *unit* (declared in *unit.h*). See *user_unit.h*.

unit data Refers to data members declared in the classes *unit*, *user_unit*, *cvu_4194*, or any unit classes created with the *mk_unit* script.

unit function Refers to functions declared in the classes *unit*, *user_unit*, *cvu_4194*, or any unit classes created with the *mk_unit* script.

user sweep The opposite of internal sweep. A sweep in which the associated unit is not completely programmed beforehand, but instead forces and measures each point under explicit supervision by IC-CAP. Unless an instrument supports 2 internal sweeps, any non-main sweep is a user sweep. Often called spot mode.

user_instr_options Class from which OMI instrument options editors are directly derived, as in:

```
class hp4194_table : public user_instr_options {...};
```

virtual function The effect of the *virtual* keyword is that when *Measurer* invokes *zero_supply()* for a unit, the actual function executed depends on the unit. If the unit is a *cvu_4194*, the code that executes is *cvu_4194::zero_supply()*. This feature is often termed *dynamic binding*. An example from *unit.h* is:

```
virtual int zero_supply() { return 0; }
```

void In C++ and ANSI/C, a function can be declared to return nothing, using the special type *void*. For example:

```
void wait_delay_time() ; // from user_meas.hxx
```

B
Agilent EEBJT2 Model Equations

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Base-Emitter and Base-Collector Current 796
Collector-Emitter Current 798
Base-Emitter and Base-Collector Capacitances 800
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This appendix describes the HPEEBJT2 model equations used in IC-CAP.

Constants

Extrinsic components including CXBC, CXBE, CXCE, LB, LC, LE, RB, RC, and RE are constants.

Base-Emitter and Base-Collector Current

The base-emitter current in the BJT has been changed significantly from the Gummel-Poon and other earlier models. These models assume that the non-leakage base-emitter current is related to the collector-emitter current by a simple constant, known as beta. Observation of base-emitter current in both silicon and AlGaAs devices has shown that this assumption is incorrect. Difficulties with this method of modeling base current have been observed for many years. A large, very bias-dependent base resistance in the modified Gummel-Poon model in Berkeley SPICE has been used to attempt to correct the problem with the base-emitter current expressions. This base resistance value and its variation is often extracted from DC data only, with the result that the behavior of the device over frequency is often poorly modeled. This problem is then *solved* by assigning some fraction of the base-collector capacitance to either side of the base in a distributed manner.

Agilent EEsof's experience with Agilent EEBJT2 has shown that properly modeled base-emitter current and conductance renders both the large bias-dependent base resistance and distributed base-collector capacitance unnecessary and greatly improves both the DC and AC accuracy of the resulting model.

Agilent EEBJT2 models the base-emitter current with 2 non-ideal exponential expressions, 1 for the bulk recombination current (usually dominant in silicon devices), and 1 for other recombination currents (usually attributed to surface leakage).

$$Ibe = \left(IBIF \bullet \left(exp(\frac{Vbe}{(NBF \bullet V_T)}) - 1.0\right)\right) + \left(ISE \bullet \left(exp(\frac{Vbe}{(NE \bullet V_T)}) - 1.0\right)\right)$$

where

$$V_T = \frac{k \bullet TAMB}{q}$$

where

k is Boltzmann's constant, and q is elementary charge.

Note that NBF is not necessarily 1.0, which is effectively the case in the Gummel-Poon model.

The base-collector current is similarly modeled:

$$Ibc = \left(IBIR \bullet \left(exp(\frac{Vbc}{(NBR \bullet V_T)}) - 1.0\right)\right) + \left(ISC \bullet \left(exp(\frac{Vbc}{(NC \bullet V_T)}) - 1.0\right)\right)$$

Virtually all silicon rf/microwave transistors are vertical planar devices, so the second current term containing ISC and NC is usually negligible.

The total base current Ib is the sum of Ibe and Ibc. Note that this method of modeling base current obsoletes the concept of a constant beta.

Collector-Emitter Current

The forward and reverse components of the collector-emitter current are modeled in a manner very similar to the Gummel-Poon model, but with somewhat more flexibility. Observation of collector-emitter current behavior has shown that the forward and reverse components do not necessarily share identical saturation currents, as in the Gummel-Poon model. The basic expressions in Agilent EEBJT2, not including high-level injection effects and Early effects, are:

$$Icf = ISF \bullet \left(exp(\frac{Vbe}{(NF \bullet V_T)}) - 1.0 \right)$$

$$Icr = ISR \bullet \left(exp(\frac{Vbc}{(NR \bullet V_T)}) - 1.0 \right)$$

where ISF and ISR are not exactly equal but are usually very close. NF and NR are not necessarily equal or 1.0, but are usually very close. Careful control of ambient temperature during device measurement is required for precise extraction of all of the saturation currents and emission coefficients in the model.

The effects of high-level injection and bias-dependent base charge storage are modeled via a normalized base charge, in a manner similar to the Gummel-Poon model:

$$Ice = \frac{(Icf - Icr)}{Qb}$$

where

$$Qb = \left(\frac{Q1}{2.0} \right) \bullet (1.0 + \sqrt{1.0 + (4.0 \bullet Q2)})$$

and

$$Q1 = \frac{1.0}{\left(1.0 - \left(\frac{Vbc}{VAF}\right) - \left(\frac{Vbe}{VAR}\right)\right)}$$

$$Q2 = \left(\left(\frac{ISF}{IKF}\right) \bullet \left(exp\left(\frac{Vbe}{(NF \bullet V_T)}\right) - 1.0\right)\right) + \left(\left(\frac{ISR}{IKR}\right) \bullet \left(exp\left(\frac{Vbc}{(NR \bullet V_T)}\right) - 1.0\right)\right)$$

NOTE All computations of the exponential expressions used in the model are linearized to prevent numerical overflow or underflow at large forward or reverse bias conditions, respectively.

Base-Emitter and Base-Collector Capacitances

Diffusion and depletion capacitances are modeled for both junctions of the transistor model in a manner very similar to the Gummel-Poon model.

For Vbc ≤ FC • VJC

$$Cbc = Cbc_{diffusion} + Cbc_{depletion}$$

where

$$Cbc_{diffusion} = TR \bullet Icr$$

and

$$Cbc_{depletion} = \frac{CJC}{\left(1.0 - \left(\frac{Vbc}{VJC}\right)\right)^{MJC}}$$

For Vbc > FC • VJC

$$Cbc_{depletion} = \left(\frac{CJC}{(1.0 - FC)^{MJC}}\right) \bullet \left(1.0 + \left(\frac{MJC \bullet (Vbc - (FC \bullet VJC))}{VJC \bullet (1.0 - FC)}\right)\right)$$

For Vbe ≤ FC • VJE

$$Cbe = Cbe_{diffusion} + Cbe_{depletion}$$

where

$$Cbe_{depletion} = \frac{CJE}{\left(1.0 - \left(\frac{Vbe}{VJE}\right)\right)^{MJE}}$$

For Vbe > FC • VJE

$$Cbe_{depletion} = \left(\frac{CJE}{(1.0-FC)^{MJE}}\right) \bullet \left(1.0 + \left(\frac{MJE \bullet (Vbe - (FC \bullet VJE))}{VJE \bullet (1.0-FC)}\right)\right)$$

The diffusion capacitance for Cbe is somewhat differently formulated vs. that of Cbc. The transit time is not a constant for the diffusion capacitance for Cbe, but is a function of both junction voltages, formulated in a manner similar to the modified Gummel-Poon model. The total base-emitter charge is equal to the sum of the base-emitter depletion charge (which is a function of Vbe only) and the so-called transit charge (which is a function of both Vbe and Vbc).

$$Q_{transit} = Tff \bullet \left(\frac{Icf}{Qb}\right)$$

where

$$Tff = TF \bullet \left(1.0 + \left(XTF \bullet \left(\frac{Icf}{Icf + ITF}\right)^{2.0} \bullet exp\left(\frac{Vbc}{1.44 \bullet VTF}\right)\right)\right)$$

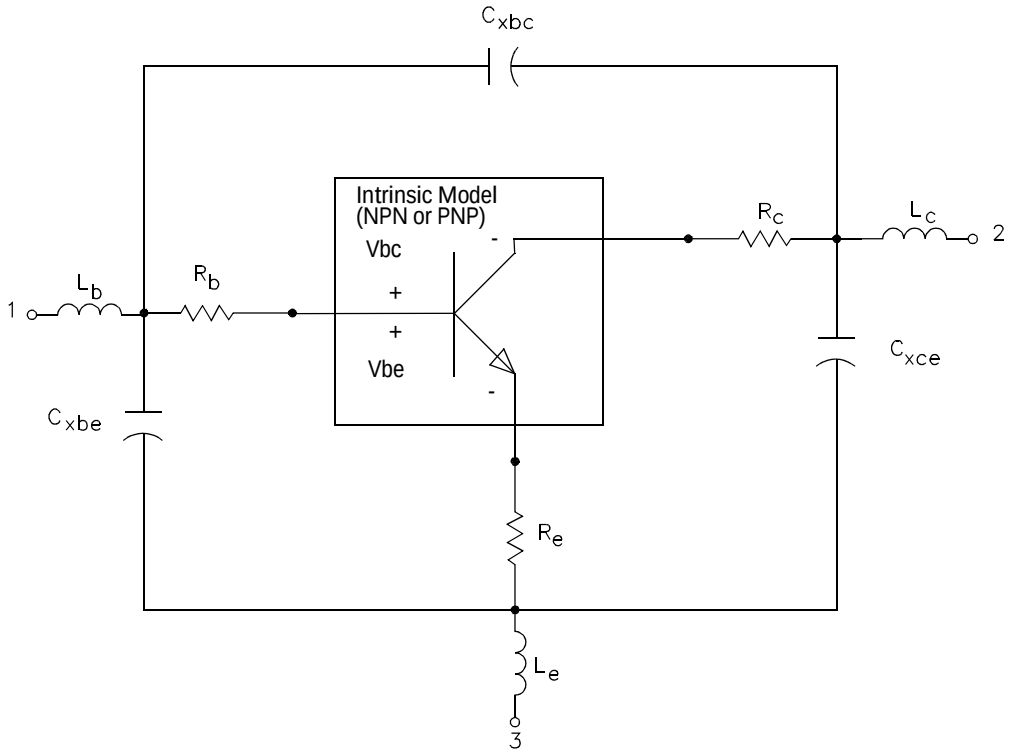
and

$$Cbe_{diffusion}(Vbe) = \frac{\partial Q_{transit}}{\partial Vbe}$$

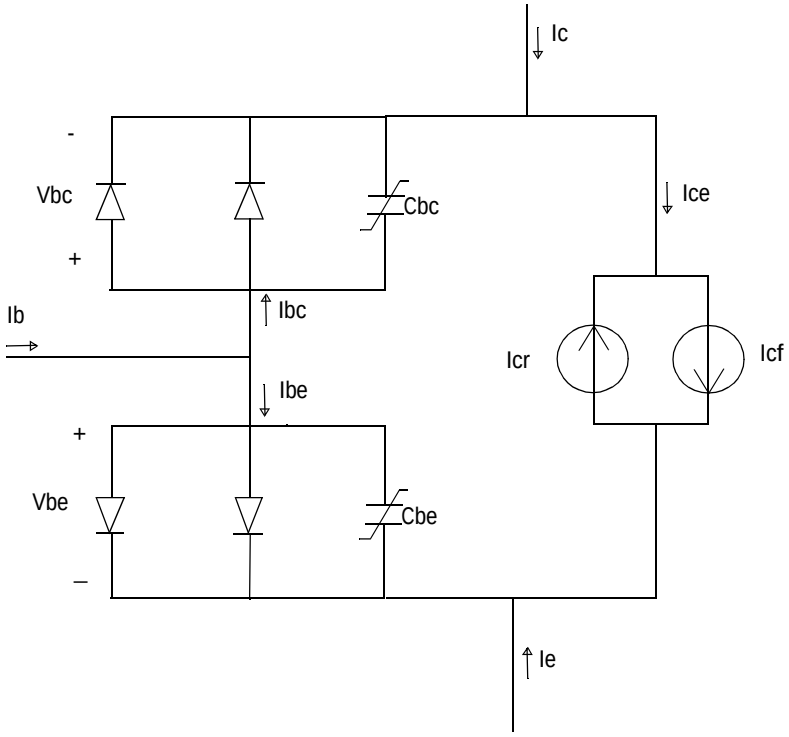
and

$$Cbe_{diffusion}(Vbc) = \frac{\partial Q_{transit}}{\partial Vbc}$$

Equivalent Circuit



Intrinsic Model



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C
Agilent EEFET3 Model Equations

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This appendix describes the HPEEFET3 model equations used in IC-CAP.

Drain-Source Current

The drain-source current model in Agilent EEFET3 is comprised of various analytic expressions that were developed through examination of g_m vs. bias plots on a wide class of devices from various manufacturers. The expressions below are given for $V_{ds} > 0.0$ V although the model is equally valid for $V_{ds} < 0.0$ V. The model assumes the device is symmetrical, and one need only replace V_{gs} with V_{gd} and V_{ds} with $-V_{ds}$ in order to obtain the reverse region ($V_{ds} < 0.0$ V) equations. The g_m, g_{ds} and I_{ds} equations take on 4 different forms depending on the value of V_{gs} relative to some of the model parameters. The I_{ds} expression is continuous through at least the second derivative everywhere.

if $V_{gs} \geq V_g$ and $V_{DELT} \leq 0.0$

$$g_{mo} = GMMAX\{1 + GAMMA(VDSO - V_{ds})\}$$

$$I_{dso} = GMMAX\left\{V_x(V_{gs}) - \frac{(VGO + VTO)}{2} + VCH\right\}$$

$$g_{dso} = -GMMAX \bullet GAMMA(V_{gs} - VCH)$$

else if $V_{DELT} > 0.0$ and $V_{gs} > V_{gb}$

$$g_{mo} = g_{mm}(V_{gb}) + m_{g_{mm}} \bullet (V_{gs} - V_{gb})$$

$$I_{dso} = g_{mm}(V_{gb}) \bullet (V_{gs} - V_{gb}) + \frac{m_{g_{mm}}}{2}(V_{gs} - V_{gb})^2 + I_{dsm}(V_{gb})$$

$$g_{dso} = \frac{\partial(g_{mm}(V_{gb}))}{\partial V_{ds}}(V_{gs} - V_{gb}) + \frac{1}{2}(V_{gs} - V_{gb})^2 \bullet \frac{\partial m_{g_{mm}}}{\partial V_{ds}} - \frac{\partial V_{gb}}{\partial V_{ds}} g_{mo}$$

else if $V_{gs} \leq V_t$

$$g_{mo} = 0.0$$

$$I_{dso} = 0.0$$

$$g_{dso} = 0.0$$

else

$$g_{mo} = g_{mm}(V_{gs})$$

$$I_{dso} = I_{dsm}(V_{gs})$$

$$g_{dso} = -\frac{GMMAX}{2} GAMMA(V_{gs} - VCH) \bullet \left\{ \cos\left[\pi \bullet \frac{V_x(V_{gs}) - (VGO - VCH)}{VTO - VGO} \right] + 1 \right\}$$

where

$$g_{mm}(V) = \frac{GMMAX}{2}[1 + GAMMA(VDSO - V_{ds})] \bullet \left\{ \cos\left[\pi \bullet \frac{V_x(V) - (VGO - VCH)}{VTO - VGO} \right] + 1 \right\}$$

$$I_{dsm}(V) = \frac{GMMAX}{2}\left(((VTO - VGO)/\pi) \sin\left[\pi \bullet \frac{V_x(V) - (VGO - VCH)}{VTO - VGO} \right] + V_x(V) - (VTO - VCH) \right)$$

$$V_x(V) = (V - VCH)[1 + GAMMA(VDSO - V_{ds})]$$

$$V_g = \frac{VGO - VCH}{1 + GAMMA(VDSO - V_{ds})} + VCH$$

$$V_t = \frac{VTO - VCH}{1 + GAMMA(VDSO - V_{ds})} + VCH$$

$$V_{gb} = \frac{(VGO - VDELT) - VCH}{1 + GAMMA(VDSO - V_{ds})} + VCH$$

$$m_{g_{mm}} = \left.\frac{\partial g_{mm}}{\partial V}\right|_{V = V_{gb}}$$

$$= -\frac{GMMAX \bullet \pi}{2(VTO - VGO)}[1 + GAMMA(VDSO - V_{ds})]^2$$

$$\bullet \sin\left[-\pi \bullet \frac{VDELT}{VTO - VGO}\right]$$

$$g_{mm}(V_{gb}) = \frac{GMMAX}{2}[1 + GAMMA(VDSO - V_{ds})]$$

$$\bullet \left\{\cos\left[-\pi \bullet \frac{VDELT}{VTO - VGO}\right] + 1\right\}$$

$$I_{dsm}(V_{gb}) = \frac{GMMAX}{2}\left(((VTO - VGO)/\pi)\sin\left[-\pi \bullet \frac{VDELT}{VTO - VGO}\right]\right.$$

$$\left. + (VGO - VDELT - VTO)\right)$$

$$\frac{\partial(g_{mm}(V_{gb}))}{\partial V_{ds}} = -\frac{GMMAX}{2}GAMMA\left\{\cos\left[-\pi \bullet \frac{VDELT}{VTO - VGO}\right] + 1\right\}$$

$$\frac{\partial m_{g_{mm}}}{\partial V_{ds}} = \frac{GMMAX \bullet \pi}{(VTO - VGO)}(GAMMA)[1 + GAMMA(VDSO - V_{ds})]$$

$$\bullet \sin\left[-\pi \bullet \frac{VDELT}{VTO - VGO}\right]$$

$$\frac{\partial V_{gb}}{\partial V_{ds}} = \frac{(VGO - VDELT) - VCH}{[1 + GAMMA(VDSO - V_{ds})]^2} \bullet GAMMA$$

The preceding relations for I_{dso}, g_{mo} and g_{dso} can now be substituted in the following equations that model the current saturation and output conductance. This portion of the model can be recognized from the work of Curtice [1].

$$g'_m = g_{mo}(1 + KAPA \bullet V_{ds})\tanh\left(\frac{3V_{ds}}{VSAT}\right)$$

$$I'_{ds} = I_{dso}(1 + KAPA \bullet V_{ds})\tanh\left(\frac{3V_{ds}}{VSAT}\right)$$

$$g'_{ds} = \{g_{dso}(1 + KAPA \bullet V_{ds}) + I_{dso}KAPA\}\tanh\left(\frac{3V_{ds}}{VSAT}\right)$$

$$+ I_{dso} \bullet \frac{3(1 + KAPA \bullet V_{ds})}{VSAT}\operatorname{sech}^2\left(\frac{3V_{ds}}{VSAT}\right)$$

These expressions do an excellent job of fitting GaAs FET I-V characteristics in regions of low power dissipation; they will also fit pulsed (isothermal) I-V characteristics. To model negative conductance effects due to self-heating, the thermal model of Canfield was incorporated [2]. With this final enhancement, the DC expressions for I_{ds} and associated conductances become:

$$I_{ds} = \frac{I'_{ds}}{1 + \frac{P_{diss}}{PEFF}}$$

$$g_m = \frac{g'_m}{\left[1 + \frac{P_{diss}}{PEFF}\right]^2}$$

$$g_{ds} = \frac{g'_{ds} - \frac{I'^2_{ds}}{PEFF}}{\left[1 + \frac{P_{diss}}{PEFF}\right]^2}$$

where

$$P_{diss} = I'_{ds} V_{ds}$$

Qualitatively, the operation of the drain-source model can be described as follows:

The V_{ds} dependence of the equations is dominated by the parameters VSAT, GAMMA, KAPA, and PEFF. Isothermal output conductance is controlled by GAMMA and KAPA. The impact of GAMMA on output conductance is more significant near threshold. At V_{gs}=VCH, the output conductance is controlled only by KAPA. The parameter PEFF provides a correction to the isothermal model for modeling the self-heating effects manifested as a negative resistance on the I-V curves. The parameter VSAT represents the drain-source voltage at which the current saturates and output conductance becomes a constant (approximately).

The overall impact of VCH on the I-V characteristics is second order at best, and many different values of VCH will provide good fits to I-V plots. For most applications encountered, it is our experience that the default value of 1.0V is an adequate value for VCH. Similar to VCH, VDSO is

a parameter that should be set rather than optimized. At V_{ds}=VDSO, the drain-source model collapses to a single voltage dependency in V_{gs}. It is recommended that the user set VDSO to a typical V_{ds} operating point in saturation. At this point, many of the parameters can be extracted right off a I_{ds}-V_{gs} plot for V_{ds}=VDSO or preferably, a g_m(DC)-V_{gs} plot at V_{ds}=VDSO.

When V_{ds}=VDSO and PEFF is set large (to disable the self-heating model), the significance of the parameters VTO, VGO, VDELT, GMMAX are easily understood from a plot of g_m(DC)-V_{gs}. GMMAX is the peak constant transconductance of the model that occurs at V_{gs}=VGO. The parameter VTO represents the gate-source voltage where g_m goes to zero. If VDELT is set to a positive value, then it causes the transconductance to become linear at V_{gs} = VGO - VDELT with a slope equal to that of the underlying cosine function at this voltage. The parameter definitions are illustrated in the following figure.

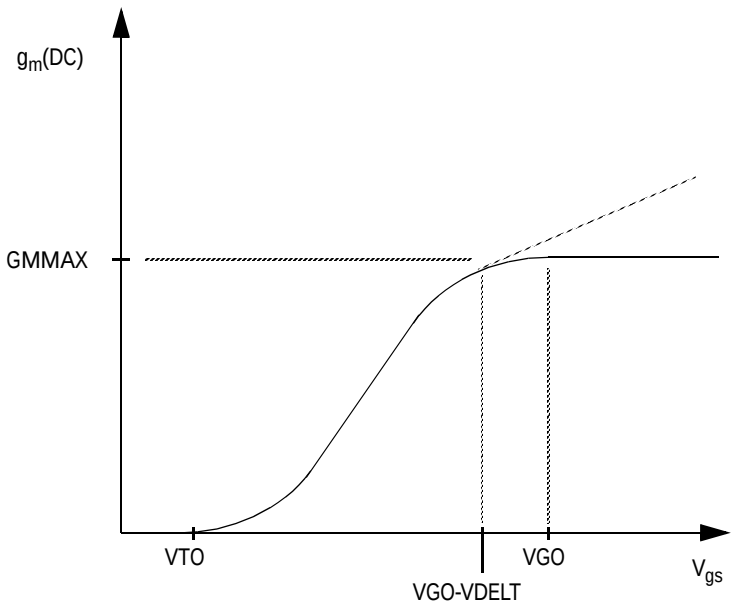


Figure 21 Agilent EEFET3 g_m-V_{gs} Parameters

Dispersion Current (Idb)

Dispersion in a GaAs MESFET drain-source current is evidenced by the observation that the output conductance and transconductance beyond some transition frequency is higher than that inferred by the DC measurements. A physical explanation often attributed to this phenomenon is that the channel carriers are subject to being trapped in the channel-substrate and channel-surface interfaces. Under slowly varying signal conditions, the rate at which electrons are trapped in these sites is equal to the rate at which they are emitted back into the channel. Under rapidly varying signals, the traps cannot follow the applied signal and the *high-frequency* output conductance results.

The circuit used to model conductance dispersion consists of the elements RDB, CBS (these linear elements are also parameters) and the nonlinear source $I_{db}(V_{gs}, V_{ds})$. The model is a large-signal generalization of the dispersion model proposed by Golio et al. [3]. At DC, the drain-source current is just the current I_{ds}. At high frequency (well above the transition frequency), the drain source current will be equal to I_{ds}(high frequency) = I_{ds}(DC) + I_{db}. Linearization of the drain-source model yields the following expressions for y_{21} and y_{22} of the intrinsic Agilent EEFET3 model.

$$y_{21} = g_{dsgs} + g_{dbgs} - \frac{g_{dbgs}}{1 + j\omega \bullet CBS \bullet RDB}$$

$$y_{22} = g_{dsds} + g_{dbds} + \frac{1}{RDB} - \frac{\left(g_{dbds} + \frac{1}{RDB}\right)}{1 + j\omega \bullet CBS \bullet RDB}$$

where

$$g_{dsgs} = \frac{\partial I_{ds}}{\partial V_{gs}}$$

$$g_{dsds} = \frac{\partial I_{ds}}{\partial V_{ds}}$$

$$g_{dbgs} = \frac{\partial I_{db}}{\partial V_{gs}}$$

$$g_{dbds} = \frac{\partial I_{db}}{\partial V_{ds}} .$$

Evaluating these expressions at the frequencies ω=0 and ω=infinity produces the following results for transconductance and output conductance:

For ω=0,

$$Re[y_{21}] = g_m = g_{dsgs}$$

$$Re[y_{22}] = g_{ds} = g_{dsds}$$

For ω=infinity,

$$Re[y_{21}] = g_m = g_{dsgs} + g_{dbgs}$$

$$Re[y_{22}] = g_{ds} = g_{dsds} + g_{dbds} + \frac{1}{RDB}$$

Between these 2 extremes, the conductances make a smooth transition, the abruptness of which is governed by the time constant τ_{disp} = RDB • CBS. The frequency f_0 at which the conductances are midway between these 2 extremes is defined as

$$f_0 = \frac{1}{2\pi\tau_{disp}}$$

The parameter RDB should be set large enough so that its contribution to the output conductance is negligible. Unless you are specifically interested in simulating the device near f_0, the default values of RDB and CBS will be adequate for most microwave applications.

The Agilent EEFET3 I_{ds} model can be extracted to fit either DC or AC characteristics. In order to simultaneously fit both DC I-Vs and AC conductances, Agilent EEFET3 utilizes a simple scheme for modeling the I_{db} current source whereby different values of the same parameters can be used in the I_{ds} equations. The DC and AC drain-source currents can be expressed as follows:

$$I_{ds}^{DC}(Voltages, Parameters) = I_{ds}(Voltages, GMMAX, VDELT, VTO, \text{GAMMA},$$

$$KAPA, PEFF, VTSO, VGO, VCH, VDSO, VSAT)$$

$$I_{ds}^{AC}(Voltages, Parameters) = I_{ds}(Voltages, GMMAXAC, VDELTAC, VTOAC,$$

$$GAMMAAC, KAPAAC, PEFFAC, VTSOAC, VGO, VCH, VDSO, VSAT)$$

Parameters such as VGO that do not have an AC counterpart (i.e., there is no VGOAC parameter) have been found not to vary significantly between extractions utilizing DC measurements versus those utilizing AC measurements. The difference between the AC and DC values of I_{ds}, plus an additional term that is a function of V_{ds} only, gives the value of I_{db} for the dispersion model

$$I_{db}(V_{gs}, V_{ds}) = I_{ds}^{AC}(V_{gs}, V_{ds}) - I_{ds}^{DC}(V_{gs}, V_{ds}) + I_{dbp}(V_{ds})$$

where I_{dbp} and its associated conductance are given by:

For V_{ds} > VDSM and $KDB \neq 0$,

$$I_{dbp} = \sqrt{\frac{GDBM}{KDB}}\tan^{-1}((V_{ds} - VDSM)\sqrt{KDB \bullet GDBM}) + GDBM \bullet VDSM$$

$$g_{dbp} = \frac{GDBM}{\left(KDB \bullet GDBM(V_{ds} - VDSM)^2 + 1\right)}$$

For V_{ds} < -VDSM and $KDB \neq 0$,

$$I_{dbp} = \sqrt{\frac{GDBM}{KDB}}\tan^{-1}((V_{ds} + VDSM)\sqrt{KDB \bullet GDBM}) - GDBM \bullet VDSM$$

$$g_{dbp} = \frac{GDBM}{\left(KDB \bullet GDBM(V_{ds} + VDSM)^2 + 1\right)}$$

For $-VDSM \leq V_{ds} \leq VDSM$ or $KDB = 0$,

$$I_{dsm} = GDBM \bullet V_{ds}$$

$$g_{dbm} = GDBM$$

By setting the 7 high-frequency parameters equal to their DC counterparts, the dispersion model reduces to $I_{db} = I_{dbp}$. Examination of the I_{dbp} expression reveals that the additional setting of GDBM to zero disables the dispersion model entirely. Since the I_{dbp} current is a function of V_{ds} only, it will impact output conductance only. However, the current function I_{ds}^{AC} will impact both g_m and g_{ds}. For this reason, the model is primarily intended to utilized g_m data as a means for tuning I_{ds}^{AC}. Once this *fitting* is accomplished, the parameters GDBM, KDB and VDSM can be tuned to optimize the g_{ds} fit.

Gate Charge Model

The Agilent EEFET3 gate charge model was developed through careful examination of extracted device capacitances over bias. The model consists of simple closed form charge expressions whose derivatives fit observed bias dependencies in capacitance data. This capacitance data can be obtained directly from measured Y-parameter data.

$$C_{11} = \frac{im[y_{11}]}{\omega} = \frac{\partial q_g}{\partial V_{gs}}$$

$$C_{12} = \frac{im[y_{12}]}{\omega} = \frac{\partial q_g}{\partial V_{ds}}$$

The capacitance data is remarkably self-consistent. In other words, a single q_g function's derivatives will fit both C_{11} data and C_{12} data. The Agilent EEFET3 gate charge expression is:

$$q_g(V_j, V_o) = \left[\frac{(C11O - C11TH)}{2} g(V_j) + C11TH(V_j - VINFL)\right] \bullet [1 + LAMBDA \bullet (V_o - VDSO)] - C12SAT \bullet V_o$$

where

$$g(V_j) = V_j - VINFL + \frac{DELTGS}{3}\log\left(\cosh\left(\frac{3}{DELTGS}(V_j - VINFL)\right)\right)$$

This expression is valid for both positive and negative V_{ds}. Symmetry is forced through the following smoothing functions proposed by Statz [4]:

$$V_j = \frac{1}{2}\left(2V_{gs} - V_{ds} + \sqrt{V_{ds}^2 + DELTDS^2}\right)$$

$$V_o = \sqrt{V_{ds}^2 + DELTDS^2}$$

Differentiating the gate charge expression wrt V_{gs} yields the following expression for the gate capacitance C_{11}:

$$C_{11}(V_j, V_o) = \left[\frac{(C11O - C11TH)}{2} \bullet g'(V_j) + C11TH\right] \bullet [1 + LAMBDA \bullet (V_o - VDSO)]$$

where

$$g'(V_j) = \frac{dg(V_j)}{dV_j} = 1 + \tanh\left[\frac{3}{DELTGS}(V_j - VINFL)\right]$$

The gate transcapacitance C_{12} is defined as:

$$C_{12}(V_j, V_o) = \frac{\partial q_g}{\partial V_{ds}} = \frac{\partial q_g}{\partial V_j}\frac{\partial V_j}{\partial V_{ds}} + \frac{\partial q_g}{\partial V_o}\frac{\partial V_o}{\partial V_{ds}}$$

$$= C_{11}(V_j, V_o) \bullet \frac{1}{2}\left[\frac{V_{ds}}{\sqrt{V_{ds}^2 + DELTDS^2}} - 1\right]$$

$$+ \left[\left[\frac{C110 - C11TH}{2} gV_j\right] + C11THV_j - VINFL\right] \bullet LAMBDA - C12SAT \bullet \frac{V_{ds}}{\sqrt{V_{ds}^2 + DELTDS^2}}$$

The Agilent EEFET3 topology requires that the gate charge be subdivided between the respective charge sources q_{gc} and q_{gy}. Although simulation could be performed directly from

the nodal gate charge q_g, division of the charge into branches permits the inclusion of the resistances RIS and RID that model charging delay between the depletion region and the channel. Agilent EEFET3 assumes the following form for the gate-drain charge in saturation:

$$q_{gy}(V_{gy}) = CGDSAT \bullet V_{gy} + q_{gyo}$$

which gives rise to a constant gate-drain capacitance in saturation. The gate-source charge q_{gc} can now be obtained by subtracting the latter from the gate charge equation. Smoothing functions can then be applied to these expressions in saturation in order to extend the model's applicable bias range to all V_{ds} values.

These smoothing functions force symmetry on the q_{gy} and q_{gc} charges such that

$$q_{gy} = q_{gc} = \frac{q_g}{2}$$

at $V_{gc} = V_{gy}$. Under large negative V_{ds} (saturation at the source end of the device), q_{gy} and q_{gc} swap roles, i.e:

$$q_{gc}(V_{gc}) = CGDSAT \bullet V_{gc} + q_{gco}$$

The following continuous charge equations satisfy these constraints and are specified in terms of the gate charge:

$$q_{gy}(V_{gc}, V_{gy}) = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gc}\} \bullet f_2 + CGDSAT \bullet V_{gy} \bullet f_1$$

$$q_{gc}(V_{gc}, V_{gy}) = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gy}\} \bullet f_1 + CGDSAT \bullet V_{gc} \bullet f_2$$

where f_1 and f_2 are smoothing functions defined by

$$f_1 = \frac{1}{2}\left[1 + \tanh\left(\frac{3}{DELTDS}(V_{gc} - V_{gy})\right)\right]$$

and

$$f_2 = \frac{1}{2}\left[1 - \tanh\left(\frac{3}{DELTDS}(V_{gc} - V_{gy})\right)\right]$$

The capacitances associated with these *branch* charge sources can be obtained through differentiation of the q_{gc} and q_{gy} equations and by application of the chain rule to the capacitances C_{11} and C_{12}. The gate charge derivatives re-formulated in terms of V_{gc} and V_{gy} are:

$$C_{ggy} = \frac{\partial q_g}{\partial V_{gy}} = -C_{12}(V_{gc}, V_{gc} - V_{gy})$$

$$C_{ggc} = \frac{\partial q_g}{\partial V_{gc}} = C_{11}(V_{gc}, V_{gc} - V_{gy}) + C_{12}(V_{gc}, V_{gc} - V_{gy})$$

The branch charge derivatives are:

$$C_{gygy} = \frac{\partial q_{gy}}{\partial V_{gy}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gc}\} \bullet \frac{\partial f_2}{\partial V_{gy}}$$

$$+ f_2 \bullet C_{ggy} + CGDSAT \bullet \left[V_{gy} \bullet \frac{\partial f_1}{\partial V_{gy}} + f_1\right]$$

$$C_{gygc} = \frac{\partial q_{gy}}{\partial V_{gc}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gc}\} \bullet \frac{\partial f_2}{\partial V_{gc}}$$

$$+ f_2 \bullet [C_{ggc} - CGDSAT] + CGDSAT \bullet V_{gy} \bullet \frac{\partial f_1}{\partial V_{gc}}$$

$$C_{gcgc} = \frac{\partial q_{gc}}{\partial V_{gc}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gy}\} \bullet \frac{\partial f_1}{\partial V_{gc}}$$

$$+ f_1 \bullet C_{ggc} + CGDSAT \bullet \left[V_{gc} \bullet \frac{\partial f_2}{\partial V_{gc}} + f_2 \right]$$

$$C_{gcgy} = \frac{\partial q_{gc}}{\partial V_{gy}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gy}\} \bullet \frac{\partial f_1}{\partial V_{gy}}$$

$$+ f_1 \bullet [C_{ggy} - CGDSAT] + CGDSAT \bullet V_{gc} \bullet \frac{\partial f_2}{\partial V_{gy}}$$

where

$$\frac{\partial f_1}{\partial V_{gc}} = \frac{3}{2 \bullet DELTDS} \operatorname{sech}^2\left(\frac{3(V_{gc} - V_{gy})}{DELTDS}\right)$$

$$\frac{\partial f_1}{\partial V_{gy}} = -\frac{\partial f_1}{\partial V_{gc}}$$

$$\frac{\partial f_2}{\partial V_{gc}} = -\frac{\partial f_1}{\partial V_{gc}}$$

$$\frac{\partial f_2}{\partial V_{gy}} = \frac{\partial f_1}{\partial V_{gc}}$$

When V_{ds}=VDSO and VDSO>>DELTDS, the gate capacitance C_{11} reduces to a single voltage dependency in V_{gs}. Similar to the I_{ds} model then, the majority of the important gate charge parameters can be estimated from a single trace of a plot. In this case, the plot of interest is C_{11}-V_{gs} at V_{ds} = VDSO.

The parameter definitions are illustrated in the following figure. The parameter DELTDS models the gate capacitance transition from the linear region of the device into saturation. LAMBDA models the slope of the C_{11}-V_{ds} characteristic in saturation. C12SAT is used to fit the gate transcapacitance (C_{12}) in saturation.

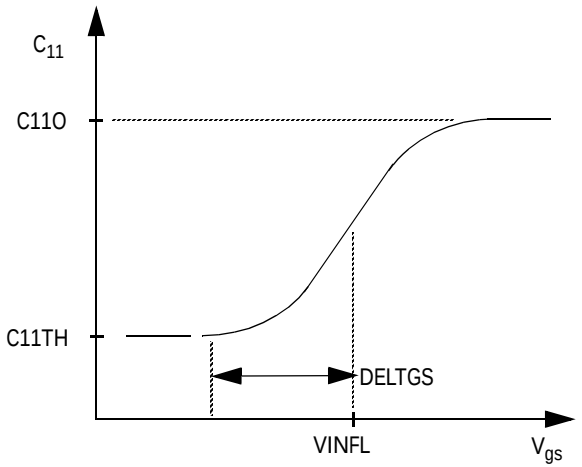


Figure 22 Agilent EEFET3 C_{11}-V_{gs} Parameters

Output Charge and Delay

Agilent EEFET3 uses a constant output capacitance specified with the parameter CDSO. This gives rise to a drain-source charge term of the form

$$q_{ds}(V_{ds}) = CDSO \bullet V_{ds}$$

The drain-source current previously described in this section is delayed with the parameter TAU according to the following equation:

$$I_{ds}(t) = I_{ds}(V_{gs}(t - TAU), V_{ds}(t))$$

In the frequency domain, only the transconductance is impacted by this delay and the familiar expression for transconductance is obtained:

$$y_m = g_m \bullet \exp(-j \bullet \omega \bullet TAU)$$

Gate Forward Conduction and Breakdown

Forward conduction in the gate junction is modeled using a standard 2-parameter diode expression. The current for this gate-source current is:

$$I_{gs}(V_{gs}) = IS \bullet \left[e^{\frac{qV_{gs}}{nkT}} - 1 \right]$$

where q is the charge on an electron, k is Boltzmann's constant and T is the junction temperature.

The Agilent EEFET3 breakdown model was developed from measured DC breakdown data and includes the voltage dependency of both gate-drain and gate-source junctions. Agilent EEFET3 models breakdown for V_{ds}>0V only, breakdown in the V_{ds}<0V region is not handled. The model consists of 4 parameters that are easily optimized to measured data. The breakdown current is given by:

For $-V_{gd} > VBR$

$$I_{gd}(V_{gd}, V_{gs}) = -KBK\left[1 - \frac{Ids(V_{gs}, V_{ds})}{IDSOC}\right] \bullet (-V_{gd} - VBR)^{NBR}$$

For $-V_{gd} \le VBR$

$$I_{gd}(V_{gd}, V_{gs}) = 0$$

Some care must be exercised in setting IDSOC. This parameter should be set to the maximum value attainable by I_{ds}. This precludes the possibility of the gate-drain current flowing in the wrong direction.

Scaling Relations

Scaling of Agilent EEFET3 model parameters is accomplished through the use of the MDIF parameters UGW and NGF and the device parameters UGW (same name as the MDIF parameter) and N. From these 4 parameters, the following scaling relations can be defined:

$$sf = \frac{UGW^{new} \bullet N}{UGW \bullet NGF}$$

$$sfg = \frac{UGW \bullet N}{UGW^{new} \bullet NGF}$$

where UGW^{new} represents the device parameter UGW, the *new* unit gate width.

Scaling will be disabled if any of the 4 scaling parameters are set to 0. The new Agilent EEFET3 parameters are computed internally by the simulator according to the following equations:

$$RIS^{new} = \frac{RIS}{sf}$$

$$RID^{new} = \frac{RID}{sf}$$

$$GMMAX^{new} = GMMAX \bullet sf$$

$$GMMAXAC^{new} = GMMAXAC \bullet sf$$

$$PEFF^{new} = PEFF \bullet sf$$

$$PEFFAC^{new} = PEFFAC \bullet sf$$

$$RDB^{new} = \frac{RDB}{sf}$$

$$GDBM^{new} = GDBM \bullet sf$$

$$KDB^{new} = \frac{KDB}{sf}$$

$$IS^{new} = IS \bullet sf$$

$$KBK^{new} = KBK \bullet sf$$

$$IDSOC^{new} = IDSOC \bullet sf$$

$$RG^{new} = \frac{RG}{sfg}$$

$$RD^{new} = \frac{RD}{sf}$$

$$RS^{new} = \frac{RS}{sf}$$

$$CBS^{new} = CBS \bullet sf$$

$$C11O^{new} = C11O \bullet sf$$

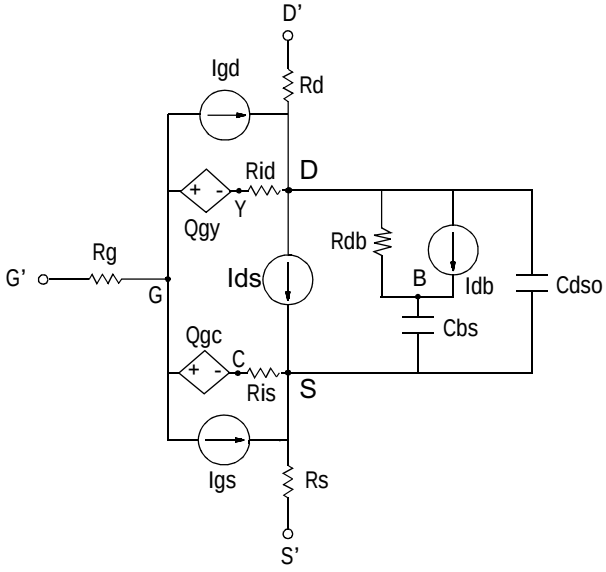
$$C11TH^{new} = C11TH \bullet sf$$

$$C12SAT^{new} = C12SAT \bullet sf$$

$$CGDSAT^{new} = CGDSAT \bullet sf$$

$$CDSO^{new} = CDSO \bullet sf$$

Equivalent Circuit



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This appendix describes the Agilent EEHEMT model equations used in IC-CAP.

Drain-Source Current

The drain-source current model in Agilent EEHEMT1 is comprised of various analytic expressions that were developed through examination of g_m vs. bias plots on a wide class of devices from various manufacturers. The expressions below are given for $V_{ds} > 0.0$ V although the model is equally valid for $V_{ds} < 0.0$ V. The model assumes the device is symmetrical, and one need only replace V_{gs} with V_{gd} and V_{ds} with $-V_{ds}$ in order to obtain the reverse region ($V_{ds} < 0.0$ V) equations. The g_m, g_{ds} and I_{ds} equations take on 4 different forms depending on the value of V_{gs} relative to some of the model parameters. The I_{ds} expression is continuous through at least the second derivative everywhere.

if $V_{gs} \geq V_g$

$$g_{mo} = GMMAX\{1 + GAMMA(VDSO - V_{ds})\}$$

$$I_{dso} = GMMAX\left\{V_x(V_{gs}) - \frac{(VGO + VTO)}{2} + VCH\right\}$$

$$g_{dso} = -GMMAX \bullet GAMMA(V_{gs} - VCH)$$

else if $V_{gs} \leq V_t$

$$g_{mo} = 0.0$$

$$I_{dso} = 0.0$$

$$g_{dso} = 0.0$$

else

$$g_{mo} = g_{mm}(V_{gs})$$

$$I_{dso} = I_{dsm}(V_{gs})$$

$$g_{dso} = -\frac{GMMAX}{2} GAMMA(V_{gs} - VCH)$$

$$\bullet \left\{ \cos\left[\pi \bullet \frac{V_x(V_{gs}) - (VGO - VCH)}{VTO - VGO} \right] + 1 \right\}$$

where

$$g_{mm}(V) = \frac{GMMAX}{2}[1 + GAMMA(VDSO - V_{ds})]$$

$$\bullet \left\{ \cos\left[\pi \bullet \frac{V_x(V) - (VGO - VCH)}{VTO - VGO} \right] + 1 \right\}$$

$$I_{dsm}(V) = \frac{GMMAX}{2}\left(((VTO - VGO)/\pi) \sin\left[\pi \bullet \frac{V_x(V) - (VGO - VCH)}{VTO - VGO} \right] \right.$$

$$\left. + V_x(V) - (VTO - VCH) \right)$$

$$V_x(V) = (V - VCH)[1 + GAMMA(VDSO - V_{ds})]$$

$$V_g = \frac{VGO - VCH}{1 + GAMMA(VDSO - V_{ds})} + VCH$$

$$V_t = \frac{VTO - VCH}{1 + GAMMA(VDSO - V_{ds})} + VCH$$

The following voltages define regions of operation that are used in the g_m compression terms:

$$V_c = VCO + MU \bullet (VDSO - V_{ds})$$

$$V_b = VBC + V_c$$

$$V_a = V_b - VBA$$

For $V_{gs} > V_c$, the basic I_{dso}, g_{mo} and g_{dso} relations are modified as follows:

for $V_{gs} < V_b$,

$$g_{mo}^{comp} = g_{mo} - g_{mv}(V_{gs}, V_{ds})$$

$$I_{dso}^{comp} = I_{dso} - I_{dsv}(V_{gs}, V_{ds})$$

$$g_{dso}^{comp} = g_{dso} - g_{dsv}(V_{gs}, V_{ds})$$

for $V_{gs} \geq V_b$ and $b \neq -1$,

$$g_{mo}^{comp} = g_{mo} - \left[a(V_{gs} - V_a)^b + g_{moff}\right]$$

$$I_{dso}^{comp} = I_{dso} - \frac{a}{b+1}\left[(V_{gs} - V_a)^{b+1} - VBA^{b+1}\right]$$

$$-g_{moff} \bullet (V_{gs} - V_b) - I_{dsv}(V_b, V_{ds})$$

$$g_{dso}^{comp} = g_{dso} - MU\left[a(V_{gs} - V_a)^b + g_{moff}\right] - g_{dsv}(V_b, V_{ds})$$

for $V_{gs} \geq V_b$ and $b = -1$

$$g_{mo}^{comp} = g_{mo} - \left[a(V_{gs} - V_a)^b + g_{moff}\right]$$

$$I_{dso}^{comp} = I_{dso} - a[\log(V_{gs} - V_a) - \log(VBA)]$$

$$-g_{moff} \bullet (V_{gs} - V_b) - I_{dsv}(V_b, V_{ds})$$

$$g_{dso}^{comp} = g_{dso} - \frac{MU \bullet a}{(V_{gs} - V_a)} - MU \bullet g_{moff} - g_{dsv}(V_b, V_{ds})$$

where

$$a = \frac{g_{mv}(V_b, V_{ds}) - g_{moff}}{VBA^b}$$

$$b = \frac{s_{vb} \bullet VBA}{g_{mv}(V_b, V_{ds}) - g_{moff}}$$

$$s_{vb} = DELTGM \bullet \frac{VBC}{\sqrt{ALPHA^2 + VBC^2}}$$

$$g_{mv}(V, V_{ds}) = DELTGM \bullet \left[\sqrt{ALPHA^2 + (V - V_c)^2} - ALPHA\right]$$

$$I_{dsv}(V, V_{ds}) = DELTGM \bullet \left(\frac{1}{2}\left((V - V_c)\sqrt{ALPHA^2 + (V - V_c)^2}\right.\right.$$

$$\left. + ALPHA^2 \bullet \log\left[\frac{(V - V_c) + \sqrt{ALPHA^2 + (V - V_c)^2}}{ALPHA}\right]\right)$$

$$\left. - ALPHA \bullet (V - V_c)\right)$$

$$g_{dsv}(V, V_{ds}) = DELTGM \bullet MU\left(\frac{1}{2}\left(\frac{2(V - V_c)^2 + ALPHA^2}{\sqrt{ALPHA^2 + (V - V_c)^2}}\right.\right.$$

$$\left. + \frac{ALPHA^2}{(V - V_c) + \sqrt{ALPHA^2 + (V - V_c)^2}}\right.$$

$$\left.\left. \bullet \left[1 + \frac{(V - V_c)}{\sqrt{ALPHA^2 + (V - V_c)^2}}\right]\right) - ALPHA\right)$$

$$g_{moff} = g_{mo}(VCO, VDSO)$$

In order to prevent g_m from becoming negative at high gate-source biases, the following restriction is placed on the parameter DELTGM:

$$DELTGM < \frac{g_{moff}}{\sqrt{ALPHA^2 + VBC^2} - ALPHA}$$

The preceding relations for I_{dso}^{comp}, g_{mo}^{comp} and g_{dso}^{comp} can now be substituted in the following equations that model the current saturation and output conductance. This portion of the model can be recognized from the work of Curtice [1].

$$g'_m = g_{mo}^{comp}(1 + KAPA \bullet V_{ds})\tanh\left(\frac{3V_{ds}}{VSAT}\right)$$

$$I'_{ds} = I_{dso}^{comp}(1 + KAPA \bullet V_{ds})\tanh\left(\frac{3V_{ds}}{VSAT}\right)$$

$$g'_{ds} = \left\{ g_{dso}^{comp}(1 + KAPA \bullet V_{ds}) + I_{dso}^{comp} KAPA \right\} \tanh\left(\frac{3V_{ds}}{VSAT}\right)$$

$$+ I_{dso}^{comp} \bullet \frac{3(1 + KAPA \bullet V_{ds})}{VSAT} \operatorname{sech}^2\left(\frac{3V_{ds}}{VSAT}\right)$$

These expressions do an excellent job of fitting HEMT I-V characteristics in regions of low power dissipation. They will also fit pulsed (isothermal) I-V characteristics. In order to model negative conductance effects due to self-heating, the thermal model of Canfield was incorporated [2]. With this final enhancement, the DC expressions for I_{ds} and its associated conductances become:

$$I_{ds} = \frac{I'_{ds}}{1 + \frac{P_{diss}}{PEFF}}$$

$$g_m = \frac{g'_m}{\left[1 + \frac{P_{diss}}{PEFF}\right]^2}$$

$$g_{ds} = \frac{g'_{ds} - \frac{I'^2_{ds}}{PEFF}}{\left[1 + \frac{P_{diss}}{PEFF}\right]^2}$$

where

$$P_{diss} = I'_{ds} V_{ds}$$

Qualitatively, the operation of the drain-source model can be described as follows:

The V_{ds} dependence of the equations is dominated by the parameters VSAT, GAMMA, KAPA, and PEFF. Isothermal output conductance is controlled by GAMMA and KAPA. The impact of GAMMA on output conductance is more significant near threshold. At V_{gs}=VCH, the output conductance is controlled only by KAPA. The parameter PEFF provides a correction to the isothermal model for modeling the self-heating effects manifested as a negative resistance on the I-V curves. The parameter VSAT represents the drain-source voltage at which the current saturates and output conductance becomes a constant (approximately). The parameter MU also impacts the I-V curves in the g_m compression region, but its effect is second order. In most cases, the g_m fit is more sensitive to the parameter MU.

The overall impact of VCH on the I-V characteristics is second order at best, and many different values of VCH will provide good fits to I-V plots. For most applications encountered, it is our experience that the default value of 1.0V is an adequate value for VCH. Similar to VCH, VDSO is a parameter that should be set rather than optimized. At V_{ds} = VDSO, the drain-source model collapses to a single voltage dependency in V_{gs}. It is recommended that the user set VDSO to a typical V_{ds} operating point in saturation. At this point, many of the parameters

can be extracted right off a I_{ds}-V_{gs} plot for V_{ds}=VDSO or, preferably, a g_m(DC)-V_{gs} plot at V_{ds}=VDSO.

When V_{ds}=VDSO and PEFF is set large (to disable the self-heating model), the significance of the parameters VTO, VGO, GMMAX, VCO, VBA, VBC, DELTGM and ALPHA are easily understood from a plot of g_m(DC)-V_{gs}. GMMAX is the peak transconductance of the model that occurs at V_{gs}=VGO. The parameter VTO represents the gate-source voltage where g_m goes to zero. Transconductance compression begins at V_{gs}=VCO. ALPHA controls the abruptness of this transition while DELTGM controls the slope of the g_m characteristic in compression. At V_{gs}=VCO+VBC, the linear g_m slope begins to tail-off and asymtotically approach zero. The shape of this “tail-off” region is controlled by the parameter VBA. The parameter definitions are illustrated in the following figure.

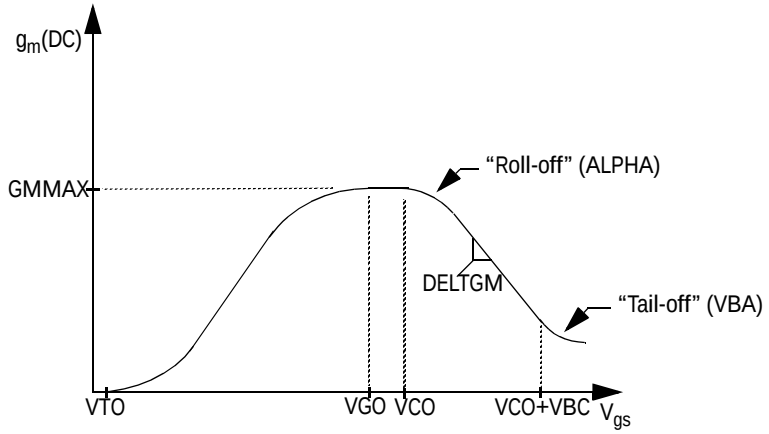


Figure 23 Agilent EEHEMT1 g_m-V_{gs} Parameters

Dispersion Current (Idb)

Dispersion in a GaAs MESFET or HEMT drain-source current is evidenced by the observation that the output conductance and transconductance beyond some transition frequency is higher than that inferred by the DC measurements. A physical explanation often attributed to this phenomenon is that the channel carriers are subject to being trapped in the channel-substrate and channel-surface interfaces. Under slowly varying signal conditions, the rate at which electrons are trapped in these sites is equal to the rate at which they are emitted back into the channel. Under rapidly varying signals, the traps cannot follow the applied signal and the *high-frequency* output conductance results.

The circuit used to model conductance dispersion consists of the elements RDB, CBS (these linear elements are also parameters) and the nonlinear source $I_{db}(V_{gs}, V_{ds})$. The model is a large-signal generalization of the dispersion model proposed by Golio et al. [3]. At DC, the drain-source current is just the current I_{ds}. At high frequency (well above the transition frequency), the drain source current will be equal to I_{ds}(high frequency) = I_{ds}(DC) + I_{db}. Linearization of the drain-source model yields the following expressions for y_{21} and y_{22} of the intrinsic Agilent EEHEMT1 model:

$$y_{21} = g_{dsgs} + g_{dbgs} - \frac{g_{dbgs}}{1 + j\omega \bullet CBS \bullet RDB}$$

$$y_{22} = g_{dsds} + g_{dbds} + \frac{1}{RDB} - \frac{\left(g_{dbds} + \frac{1}{RDB}\right)}{1 + j\omega \bullet CBS \bullet RDB}$$

where

$$g_{dsgs} = \frac{\partial I_{ds}}{\partial V_{gs}}$$

$$g_{dsds} = \frac{\partial I_{ds}}{\partial V_{ds}}$$

$$g_{dbgs} = \frac{\partial I_{db}}{\partial V_{gs}}$$

$$g_{dbds} = \frac{\partial I_{db}}{\partial V_{ds}}$$

Evaluating these expressions at the frequencies ω = 0 and ω = infinity, produces the following results for transconductance and output conductance:

for ω = 0,

$$Re[y_{21}] = g_m = g_{dsgs}$$

$$Re[y_{22}] = g_{ds} = g_{dsds}$$

for ω = infinity,

$$Re[y_{21}] = g_m = g_{dsgs} + g_{dbgs}$$

$$Re[y_{22}] = g_{ds} = g_{dsds} + g_{dbds} + \frac{1}{RDB}$$

Between these 2 extremes, the conductances make a smooth transition, the abruptness of which is governed by the time constant τ_{disp} = RDB • CBS. The frequency f_0 at which the conductances are midway between these 2 extremes is defined as

$$f_0 = \frac{1}{2\pi\tau_{disp}}$$

The parameter RDB should be set large enough so that its contribution to the output conductance is negligible. Unless the user is specifically interested in simulating the device near f_0, the default values of RDB and CBS will be adequate for most microwave applications.

The Agilent EEHEMT1 I_{ds} model can be extracted to fit either DC or AC characteristics. In order to simultaneously fit both DC I-V characteristics and AC conductances, Agilent EEHEMT1 utilizes a simple scheme for modeling the I_{db} current source whereby different values of the same parameters can be used in the I_{ds} equations. The DC and AC drain-source currents can be expressed as follows:

$$I_{ds}^{DC}(Voltages, Parameters) = I_{ds}(Voltages, GMMAX, VDELT, VTO, GAMMA, KAPA, PEFF, VTSO, DELTGM, VGO, VCH, VDSO, VSAT)$$

$$I_{ds}^{AC}(Voltages, Parameters) = I_{ds}(Voltages, GMMAXAC, VDELTAC, VTOAC, GAMMAAC, \text{KAPAAC', PEFFAC, VTSOAC, } DELTGMAC, VGO, VCH, VDSO, VSAT)$$

Parameters such as VGO that do not have an AC counterpart (i.e., there is no VGOAC parameter) have been found not to vary significantly between extractions utilizing DC measurements versus those utilizing AC measurements. The difference between the AC and DC values of Ids, plus an additional term that is a function of Vds only, gives the value of Idb for the dispersion model

$$I_{db}(V_{gs}, V_{ds}) = I_{ds}^{AC}(V_{gs}, V_{ds}) - I_{ds}^{DC}(V_{gs}, V_{ds}) + I_{dbp}(V_{ds})$$

where I_{dbp} and its associated conductance are given by:

for V_{ds} > VDSM and KDB ≠ 0,

$$I_{dbp} = \sqrt{\frac{GDBM}{KDB}} \tan^{-1}((V_{ds} - VDSM)\sqrt{KDB \bullet GDBM}) + GDBM \bullet VDSM$$

$$g_{dbp} = \frac{GDBM}{\left(KDB \bullet GDBM(V_{ds} - VDSM)^2 + 1\right)}$$

for V_{ds} < -VDSM and KDB ≠ 0,

$$I_{dbp} = \sqrt{\frac{GDBM}{KDB}} \tan^{-1}((V_{ds} + VDSM)\sqrt{KDB \bullet GDBM}) - GDBM \bullet VDSM$$

$$g_{dbp} = \frac{GDBM}{\left(KDB \bullet GDBM(V_{ds} + VDSM)^2 + 1\right)}$$

for –VDSM ≤ V_{ds} ≤ VDSM or KDB = 0,

$$I_{dsm} = GDBM \bullet V_{ds}$$

$$g_{dbm} = GDBM$$

By setting the 8 high-frequency parameters equal to their DC counterparts, the dispersion model reduces to I_{db}=I_{dbp}. Examination of the I_{dbp} expression reveals that the additional setting of GDBM to zero disables the dispersion model entirely. Since the I_{dbp} current is a function of V_{ds} only, it will impact output conductance only. However, the current function

$$I_{ds}^{AC}$$

will impact both g_m and g_{ds}. For this reason, the model is primarily intended to utilized g_m data as a means for tuning

$$I_{ds}^{AC}$$

Once this *fitting* is accomplished, the parameters GDBM, KDB and VDSM can be tuned to optimize the g_{ds} fit.

Gate Charge Model

The Agilent EEHEMT1 gate charge model was developed through careful examination of extracted device capacitances over bias. The model consists of simple closed form charge expressions whose derivatives fit observed bias dependencies in capacitance data. This capacitance data can be obtained directly from measured Y-parameter data:

$$C_{11} = \frac{im[y_{11}]}{\omega} = \frac{\partial q_g}{\partial V_{gs}}$$

$$C_{12} = \frac{im[y_{12}]}{\omega} = \frac{\partial q_g}{\partial V_{ds}}$$

The capacitance data is remarkably self-consistent. In other words, a single q_g function's derivatives will fit both C_{11} data and C_{12} data. The Agilent EEHEMT1 gate charge expression is:

$$q_g(V_j, V_o) = \left[\frac{C11O - C11TH}{2} g(V_j) + C11TH(V_j - VINFL)\right]$$

$$\bullet\,[1 + LAMBDA \bullet (V_o - VDSO)] - C12SAT \bullet V_o$$

where

$$g(V_j) = V_j - VINFL + \frac{DELTGS}{3} \ln\left(\cosh\left(\frac{3}{DELTGS}(V_j - VINFL)\right)\right)$$

This expression is valid for both positive and negative V_{ds}. Symmetry is forced through the following smoothing functions proposed by Statz [4]:

$$V_j = \frac{1}{2}\left(2V_{gs} - V_{ds} + \sqrt{V_{ds}^2 + DELTDS^2}\right)$$

$$V_o = \sqrt{V_{ds}^2 + DELTDS^2}$$

Differentiating the gate charge expression wrt V_{gs} yields the following expression for the gate capacitance C_{11}:

$$C_{11}(V_j, V_o) = \left[\frac{C11O - C11TH}{2} g'(V_j) + C11TH\right]$$

$$\bullet\,[1 + LAMBDA \bullet (V_o - VDSO)]$$

where

$$g'(V_j) = \frac{dg(V_j)}{dV_j} = 1 + \tanh\left[\frac{3}{DELTGS}(V_j - VINFL)\right]$$

The gate transcapacitance C_{12} is defined as:

$$C_{12}(V_j, V_o) = \frac{\partial q_g}{\partial V_{ds}} = \frac{\partial q_g}{\partial V_j}\frac{\partial V_j}{\partial V_{ds}} + \frac{\partial q_g}{\partial V_o}\frac{\partial V_o}{\partial V_{ds}}$$

$$= C_{11}(V_j, V_o) \bullet \frac{1}{2}\left[\frac{V_{ds}}{\sqrt{V_{ds}^2 + DELTDS^2}} - 1\right]$$

$$+ \left[\frac{C110 - C11TH}{2} g(V_j)\right] \bullet LAMBDA - C12SAT$$

$$\bullet \frac{V_{ds}}{\sqrt{V_{ds}^2 + DELTDS^2}}$$

The Agilent EEHEMT1 topology requires that the gate charge be subdivided between the respective charge sources q_{gc} and q_{gy}. Although simulation could be performed directly from

the nodal gate charge q_g, division of the charge into branches permits the inclusion of the resistances RIS and RID that model charging delay between the depletion region and the channel. Agilent EEHEMT1 assumes the following form for the gate-drain charge in saturation:

$$q_{gy}(V_{gy}) = CGDSAT \bullet V_{gy} + q_{gyo}$$

which gives rise to a constant gate-drain capacitance in saturation.

The gate-source charge q_{gc} can now be obtained by subtracting the latter from the gate charge equation. Smoothing functions can then be applied to these expressions in saturation in order to extend the model's applicable bias range to all V_{ds} values. These smoothing functions force symmetry on the q_{gy} and q_{gc} charges such that

$$q_{gy} = q_{gc} = \frac{q_g}{2}$$

at $V_{gc} = V_{gy}$. Under large negative V_{ds} (saturation at the source end of the device), q_{gy} and q_{gc} swap roles, i.e:

$$q_{gc}(V_{gc}) = CGDSAT \bullet V_{gc} + q_{gco}$$

The following continuous charge equations satisfy these constraints and are specified in terms of the gate charge:

$$q_{gy}(V_{gc}, V_{gy}) = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gc}\} \bullet f_2 + CGDSAT \bullet V_{gy} \bullet f_1$$

$$q_{gc}(V_{gc}, V_{gy}) = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gy}\} \bullet f_1 + CGDSAT \bullet V_{gc} \bullet f_2$$

where f_1 and f_2 are smoothing functions defined by

$$f_1 = \frac{1}{2}\left[1 + \tanh\left(\frac{3}{DELTDS}(V_{gc} - V_{gy})\right)\right]$$

and

$$f_2 = \frac{1}{2}\left[1 - \tanh\left(\frac{3}{DELTDS}(V_{gc} - V_{gy})\right)\right]$$

The capacitances associated with these *branch* charge sources can be obtained through differentiation of the q_{gc} and q_{gy} equations and by application of the chain rule to the capacitances C_{11} and C_{12}. The gate charge derivatives re-formulated in terms of V_{gc} and V_{gy} are:

$$C_{ggy} = \frac{\partial q_g}{\partial V_{gy}} = -C_{12}(V_{gc}, V_{gc} - V_{gy})$$

$$C_{ggc} = \frac{\partial q_g}{\partial V_{gc}} = C_{11}(V_{gc}, V_{gc} - V_{gy}) + C_{12}(V_{gc}, V_{gc} - V_{gy})$$

The branch charge derivatives are:

$$C_{gygy} = \frac{\partial q_{gy}}{\partial V_{gy}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gc}\} \bullet \frac{\partial f_2}{\partial V_{gy}}$$

$$+ f_2 \bullet C_{ggy} + CGDSAT \bullet \left[V_{gy} \bullet \frac{\partial f_1}{\partial V_{gy}} + f_1\right]$$

$$C_{gygc} = \frac{\partial q_{gy}}{\partial V_{gc}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gc}\} \bullet \frac{\partial f_2}{\partial V_{gc}}$$

$$+ f_2 \bullet [C_{ggc} - CGDSAT] + CGDSAT \bullet V_{gy} \bullet \frac{\partial f_1}{\partial V_{gc}}$$

$$C_{gcgc} = \frac{\partial q_{gc}}{\partial V_{gc}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gy}\} \bullet \frac{\partial f_1}{\partial V_{gc}}$$

$$+ f_1 \bullet C_{ggc} + CGDSAT \bullet \left[V_{gc} \bullet \frac{\partial f_2}{\partial V_{gc}} + f_2 \right]$$

$$C_{gcgy} = \frac{\partial q_{gc}}{\partial V_{gy}} = \{q_g(V_{gc}, V_{gc} - V_{gy}) - CGDSAT \bullet V_{gy}\} \bullet \frac{\partial f_1}{\partial V_{gy}}$$

$$+ f_1 \bullet [C_{ggy} - CGDSAT] + CGDSAT \bullet V_{gc} \bullet \frac{\partial f_2}{\partial V_{gy}}$$

where

$$\frac{\partial f_1}{\partial V_{gc}} = \frac{3}{2 \bullet DELTDS} \operatorname{sech}^2\left(\frac{3(V_{gc} - V_{gy})}{DELTDS}\right)$$

$$\frac{\partial f_1}{\partial V_{gy}} = -\frac{\partial f_1}{\partial V_{gc}}$$

$$\frac{\partial f_2}{\partial V_{gc}} = -\frac{\partial f_1}{\partial V_{gc}}$$

$$\frac{\partial f_2}{\partial V_{gy}} = \frac{\partial f_1}{\partial V_{gc}}$$

When V_{ds}=VDSO and VDSO>>DELTDS, the gate capacitance C_{11} reduces to a single voltage dependency in V_{gs}. Similar to the I_{ds} model, the majority of the important gate charge parameters can then be estimated from a single trace of a

plot. In this case, the plot of interest is C_{11}-V_{gs} at V_{ds} = VDSO. The parameter definitions are illustrated in the following figure.

The parameter DELTDS models the gate capacitance transition from the linear region of the device into saturation. LAMBDA models the slope of the C_{11}-V_{ds} characteristic in saturation. C12SAT is used to fit the gate transcapacitance (C_{12}) in saturation.

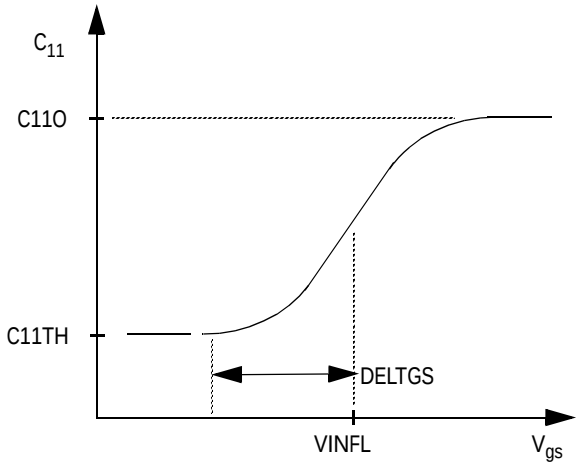


Figure 24 Agilent EEHEMT1 C_{11}-V_{gs} Parameters

Output Charge and Delay

Agilent EEHEMT1 uses a constant output capacitance specified with the parameter CDSO. This gives rise to a drain-source charge term of the form

$$q_{ds}(V_{ds}) = CDSO \bullet V_{ds}$$

The drain-source current described previously, is delayed with the parameter TAU according to the following equation:

$$I_{ds}(t) = I_{ds}(V_{gs}(t - TAU), V_{ds}(t))$$

In the frequency domain, only the transconductance is impacted by this delay and the familiar expression for transconductance is obtained

$$y_m = g_m \bullet \exp(-j \bullet \omega \bullet TAU)$$

Gate Forward Conduction and Breakdown

Forward conduction in the gate junction is modeled using a standard 2-parameter diode expression. The current for this gate-source current is:

$$I_{gs}(V_{gs}) = IS \bullet \left[e^{\frac{qV_{gs}}{nkT}} - 1 \right]$$

where q is the charge on an electron, k is Boltzmann's constant, and T is the junction temperature.

The Agilent EEHEMT1 breakdown model was developed from measured DC breakdown data and includes the voltage dependency of both gate-drain and gate-source junctions. Agilent EEHEMT1 models breakdown for Vds > 0V only, breakdown in the Vds < 0V region is not handled. The model consists of 4 parameters that are easily optimized to measured data. The breakdown current is given by:

for $-V_{gd} > VBR$

$$I_{gd}(V_{gd}, V_{gs}) = -KBK\left[1 - \frac{Ids(V_{gs}, V_{ds})}{IDSOC}\right] \bullet (-V_{gd} - VBR)^{NBR}$$

for $-V_{gd} \leq VBR$

$$I_{gd}(V_{gd}, V_{gs}) = 0$$

Some care must be exercised in setting IDSOC. This parameter should be set to the maximum value attainable by I_{ds}. This precludes the possibility of the gate-drain current flowing in the wrong direction.

Scaling Relations

Scaling of Agilent EEHEMT1 model parameters is accomplished through the use of the MDIF parameters UGW and NGF and the device parameters UGW (same name as the MDIF parameter) and N. From these 4 parameters, the following scaling relations can be defined:

$$sf = \frac{UGW^{new} \bullet N}{UGW \bullet NGF}$$

$$sfg = \frac{UGW \bullet N}{UGW^{new} \bullet NGF}$$

where UGW^{new} represents the device parameter UGW, the *new* unit gate width.

Scaling will be disabled if any of the 4 scaling parameters are set to 0. The new Agilent EEHEMT1 parameters are computed internally by the simulator according to the following equations:

$$RIS^{new} = \frac{RIS}{sf}$$

$$RID^{new} = \frac{RID}{sf}$$

$$GMMAX^{new} = GMMAX \bullet sf$$

$$GMMAXAC^{new} = GMMAXAC \bullet sf$$

$$DELTGM^{new} = DELTGM \bullet sf$$

$$DELTGMAC^{new} = DELTGMAC \bullet sf$$

$$PEFF^{new} = PEFF \bullet sf$$

$$PEFFAC^{new} = PEFFAC \bullet sf$$

$$RDB^{new} = \frac{RDB}{sf}$$

$$GDBM^{new} = GDBM \bullet sf$$

$$KDB^{new} = \frac{KDB}{sf}$$

$$IS^{new} = IS \bullet sf$$

$$KBK^{new} = KBK \bullet sf$$

$$IDSOC^{new} = IDSOC \bullet sf$$

$$RG^{new} = \frac{RG}{sfg}$$

$$RD^{new} = \frac{RD}{sf}$$

$$RS^{new} = \frac{RS}{sf}$$

$$CBS^{new} = CBS \bullet sf$$

$$C11O^{new} = C11O \bullet sf$$

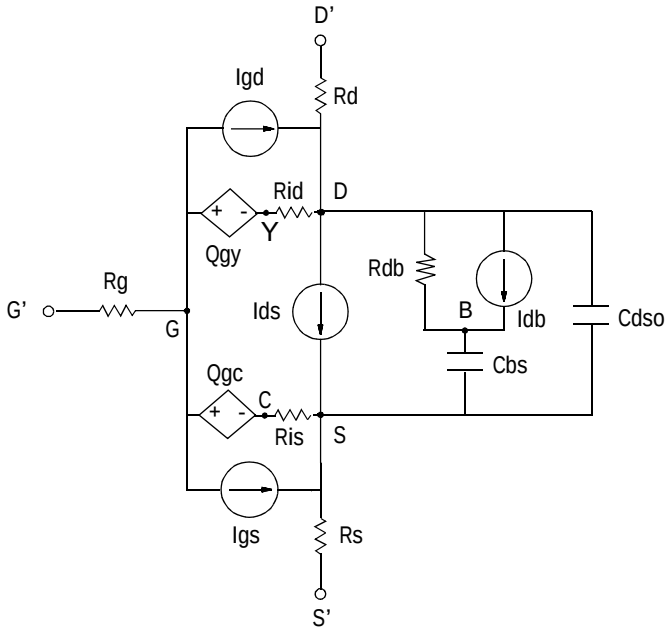
$$C11TH^{new} = C11TH \bullet sf$$

$$C12SAT^{new} = C12SAT \bullet sf$$

$$CGDSAT^{new} = CGDSAT \bullet sf$$

$$CDSO^{new} = CDSO \bullet sf$$

Equivalent Circuit



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D Agilent EEHEMT1 Model Equations

E
Controlling IC-CAP from Another Application

To Compile Using the Library 856
Details of Function Calls 858
Details of the LinkReturnS Structure 864

Other applications written in the C or C++ programming language can control IC-CAP via a library provided by IC-CAP. The library, *libiclinklibs.a*, consists of 6 function calls which enable the application to launch IC-CAP and communicate with it through an IPC (Inter-Process Communication) link.

The library allows the C application to send arbitrary PEL code to IC-CAP. The PEL code is then executed within IC-CAP. The context of the PEL code is 1 level above the macros in a Model. Therefore, the only variables available to the PEL code are the top-level System Variables. To see these variables, open the System Variables window using the menu Tools > System Variables in IC-CAP's Main window.

The library *libiclinklibs.a* contains the following calls:

```
int launch_iccap(const char *appName,
                 const char *host,
                 const char *iccapRoot,
                 const char *altPath)
int initialize_session()
int terminate_session()
int send_map(int *map, int length)
int send_PEL(const char *PELText,
             int wait,
             char **errMsg,
             LinkReturnFuncT retfunc);
int get_PEL_response(char **errMsg, LinkReturnFuncT
                     retfunc);
```

To Compile Using the Library

Other files provided by IC-CAP to establish an IPC link include the following:

Platforms	File Names
Solaris	$ICCAP_ROOT/src/iclinklib.h
Solaris	$ICCAP_ROOT/lib/sol2x/libiclinklibs.a $ICCAP_ROOT/lib/sol2x/libiclinklib.so

NOTE

In IC-CAP 2004, the name of the static library changed from *libiclinklib.a* to *libiclinklibs.a*.

To compile your application with the static library, add `-liclinklibs` to the compile command along with `-L$ICCAP_ROOT/lib/`<pltfm> `-liclinklibs` where <pltfm> is `sol2x` or `hpux10`. In general, the static library (*libiclinklibs.a*) will be sufficient, but if you want to use the shared version (*libiclinklib.sl* or *libiclinklib.so*), it is also provided. To compile your application with the shared library, add `-liclinklib` to the compile command along with `-L$ICCAP_ROOT/lib/`<pltfm> `-liclinklib` where <pltfm> is `sol2x` or `hpux10`. For the Sun compiler, use the `-Bstatic` or `-Bdynamic` option to choose between the 2 libraries.

Solaris Examples

To use the static *iclinklibs* library, and use shared libraries for all others (*libc*, etc.):

```
cc program.c -L$ICCAP_ROOT/lib/sol2x -Bstatic -liclinklibs
             -Bdynamic
```

To use static libraries for everything:

```
cc program.c -L$ICCAP_ROOT/lib/sol2x -Bstatic -liclinklibs
```

To use shared libraries for everything:

```
cc program.c -L$ICCAP_ROOT/lib/sol2x -Bdynamic -liclinklib
```

or

```
cc program.c -L$ICCAP_ROOT/lib/sol2x -liclinklib
```

Details of Function Calls

This section describes each function call available in the *libiclinklibs.a* library. The descriptions include available arguments, and the results returned, including error codes.

For an example of each function call, see the IC-CAP IPC Link example program (`$ICCAP_ROOT/src/ipcexample.c`). This example program takes control of IC-CAP. It then sends PEL commands to access variables and datasets in an npn model, performs a time-consuming task, and sends a pin mapping to IC-CAP and then accesses it.

launch_iccap

```
int launch_iccap(const char *appName,
                 const char *host,
                 const char *iccapRoot,
                 const char *altPath)
```

launch_iccap invokes IC-CAP with the IPC link in place.

appName declares the name of the invoking program. This name cannot contain any spaces. This name will appear in the interactive dialog selector in IC-CAP as well as within a menu. If *appName* is NULL or the null string, the default link name will be Unnamed_Link.

host specifies the host's name on which to run. If this string is not NULL, and if *gethostent* matches this host with *gethostbyname()*, then no *remsh* or *rsh* is used. If host is not NULL (or null string), and it returns a *hostent* with *gethostbyname*, then *remsh* or *rsh* will be used to invoke IC-CAP.

iccapRoot is the path to where IC-CAP has been installed on the machine on which it is to run. If *iccapRoot* is NULL, it is assumed that ICCAP_ROOT is or will be set in the environment and that *$ICCAP_ROOT/bin* is already in the path.

altPath identifies a different path. Ordinarily, *$ICCAP_ROOT/bin/iccap* is used to invoke IC-CAP. Users often place a wrapper around this script to set up ICCAP_ROOT and LM_LICENSE_FILE. If this is the case, the alternate script can be named in this argument.

Returns

launch_iccap returns 0 if successful, or the following error codes:

-1 - Unable to determine current host.

-2 - Unable to fork.

initialize_session()

```
int initialize_session()
```

initialize_session attempts to gain control of the current IC-CAP session. Once initialized, PEL calls can be sent. IC-CAP is placed in a special mode on success of this call which will not raise any error dialogs. It also actively listens for calls from the link.

Returns

initialize_session() returns 0 if successful, or one of the following error codes:

-1 - IC-CAP is being used interactively. Message should be presented to user in this case telling them to set IC-CAP for Linked Mode.

-2 - General Communications Failure. IC-CAP is not responding as expected. The link has been broken.

-3 - The session is already running, and waiting for a PEL response from a prior *send_PEL* with *wait*==0. *get_PEL_response* must be called.

terminate_session()

```
int terminate_session()
```

terminate_session relinquishes control of IC-CAP. This enables you to interactively use IC-CAP.

Returns

terminate_session() returns 0 if successful, or one of the following error codes:

-1 - Indicates that IC-CAP is in interactive mode.

-2 - Indicates a communications failure. When -2 is returned, the link is broken.

-3 - The session can't be terminated. Waiting for a PEL response from a prior *send_PEL* with *wait*==0. *get_PEL_response* must be called.

send_PEL

```
int send_PEL(const char *PELText, int wait, char **errMsg,
        LinkReturnFuncT retfunc)
```

send_PEL sends *PELText* across the link to be executed within IC-CAP. *initialize_session()* must have been called successfully prior to this working. The text can be multiline or a single line of code. Each call to *send_PEL* essentially begins a new macro, so temporary variables within text will not persist between *send_PEL* calls. However, temporary variables can be used within multiline *PELText*. *PELText* should be null terminated.

wait specifies if *send_PEL* should wait for the PEL to finish before returning. If *wait* is nonzero, *send_PEL* will wait. If *wait* is 0, *send_PEL* will return immediately upon sending the PEL text to IC-CAP. The caller must then, at a later time, call *get_PEL_response()* to wait for the call to complete and collect the return status. See *get_PEL_response*.

If *errMsg* is not NULL and a PEL error occurs (noted by return of -3), it will be set to point to an error message returned from IC-CAP. The message will be a null

terminated string and must be freed with *free()*. No memory is allocated if NULL is passed to *send_PEL*, or if no error occurs. *errMsg* is only meaningful when -3 is returned.

retfunc points to a function of type *LinkReturnFuncT*. This function will be invoked whenever IC-CAP calls one of the functions *ICMSchar*, *ICMSint*, *ICMSreal*, *ICMSstr*, or *ICMSarray*. The one argument to this function is a pointer to a *LinkReturnS* structure as shown in the following statement:

```
typedef int (*LinkReturnFuncT)(struct LinkReturnS *);
```

For details about the structure, see "Details of the LinkReturnS Structure" on page 864.

Returns

send_PEL() returns 0 if successful, or one of the following error codes:

-1 - Indicates that IC-CAP is in interactive mode.

-2 - Indicates a communications failure. When -2 is returned, the link is broken.

-3 - PEL was executed, but an IC-CAP error occurred. Check *errMsg* for details.

-4 - PEL could not be sent, because there is a pending response caused by a prior *send_PEL* with *wait*==0.

get_PEL_response

```
int get_PEL_response(char **errMsg, LinkReturnFuncT retfunc)
```

get_PEL_response waits PEL from a prior *send_PEL* (with *wait*==0) to complete.

If *errMsg* is not NULL and a PEL error occurred (error code -3), it will be set to point to an error message returned from IC-CAP. The message will be a null terminated string and must be freed with *free()*. No memory will be allocated if NULL is passed to *send_PEL*, or if no error occurs. *errMsg* is only meaningful when -3 is returned.

retfunc points to a function of type *LinkReturnFuncT*. This function is invoked when IC-CAP calls one of the functions *ICMSchar*, *ICMSint*, *ICMSreal*, *ICMSstr*, or *ICMSarray*. The one argument to this function is a pointer to a *LinkReturnS* structure as shown in the following statement:

```
typedef int (*LinkReturnFuncT)(struct LinkReturnS *);
```

For details about the structure, see "Details of the LinkReturnS Structure" on page 864.

Returns

get_PEL_response() returns 0 if successful, or one of the following error codes:

-1 - Indicates that IC-CAP is in interactive mode.

-2 - Indicates a communications failure. When -2 is returned, the link is broken.

-3 - PEL was executed, but an IC-CAP error occurred. Check *errMsg* for details.

-4 - There were no prior *send_PEL* calls with *wait*==0 to wait for.

send_map

```
int send_map(int *pinMap, int numPins)
```

send_map sends a new pin matrix mapping to IC-CAP for use with *ICMSpin()* or *SPECSpin()*. The indices of the *pinMap* array correspond to the actual pins in the hardware. The values of *pinMap* correspond to the logical pad numbers associated with the pins. For example, if `pinMap[5]=12`, a call to `SPECSpin(5)` would return `12`. If hardware contains no 0 pin, load `pinMap[0]` with `-1`.

Returns

send_map() returns 0 if successful, or one of the following error codes:

-1 - indicates that IC-CAP is in interactive mode.

-2 - indicates a communications failure. When -2 is returned, the link is broken.

-3 - Map cannot be sent. Waiting for a PEL response from a prior *send_PEL* with *wait*==0. *get_PEL_response* must be called.

Details of the LinkReturnS Structure

```
struct LinkReturnS {
   char type;
   int indx;
   int asize;
   union{char c_val;
         int i_val;
         double r_val;
         double *a_val;
         char *s_val;
   } value;
};
```

type is a single character denoting type of data being passed: I (Int), C (Char), R (Real), S (String) or X (array).

indx refers to the index field of an *ICMS*XXXX function call. This is the index into which ICMS is to place the data.

asize is the size of the array that is passed in. This is 1 for *type* I, C, and R. For S, it is the length of the array. For X, it is the number of points in the data array.

union contains arguments where each x_*val* corresponds to the *type* character.

F
ICCAP_FUNC Statement

The PEL statement ICCAP_FUNC replaced MENU_FUNC to reflect the fact that many objects you act on are not menu-related. (Note: Existing macros using the MENU_FUNC statement will still work but we recommend you create new macros using ICCAP_FUNC.)

The form of the PEL statement is

```
ICCAP_FUNC()
```

where () contains at least two arguments, each enclosed in quotation marks, separated by a comma

- The first argument is the name of the object on which you want to act
- The second argument is the action you want to perform
- Optional arguments can be used to anticipate prompts during execution, namely for filenames for reading or writing

An example is shown next:

```
iccap_func("/CGaas1/dc/DeviceParameterSet","Memory Store")
```

where

CGaas1	is the model name
dc	is the DUT name
DeviceParameterSet	is the object on which to act
Memory Store	is the action to perform on DeviceParameterSet (the object)

The Third Parameter

The optional arguments anticipate the need for information required to continue macro execution. If the argument is not included, and information is required, a dialog box appears prompting the user for the information. Usually, the optional arguments are file names used when reading from or writing to files. The following example shows how this optional argument is used to specify the file *fileName.mdm* from which to import data. This anticipates the need for a file name prompt and so avoids interrupting execution.

Example

```
iccap_func("CGaas1/dc/igvg_0vs","Import Data",
           "fileName.mdm")
```

To successfully create macros with the ICCAP_FUNC statement, you must understand the hierarchy of the objects and specify the exact names of objects and actions. A tree-like structure, shown next, illustrates the relationship of the objects.

IC-CAP
- Variables
- GUI Items
  - GUI Item
- Simulation Debugger
- Hardware
  - HPIB Analyzer
- PlotOptions
- MODEL(*)
  - Variables
  - GUI Items
    - GUI Item
  - Circuit
  - PlotOptimizer
  - PlotOptions
  - Parameter Set
  - MACRO(*)
  - DUT(*)
    - Variables
    - GUI Items
      - GUI Item
    - Test Circuit
    - Device Parameter Set
    - SETUP(*)
      - Variables

|– GUI Items
    |– GUI Item
|–Instrument Options
|–INPUT(*)
|–OUTPUT(*)
|–TRANSFORM(*)
|–PLOT(*)
    |– PlotOptions

When specifying objects at lower levels, you must include the related objects above them, separating them with slashes. For example, to perform Save As on an instrument options table, you would specify:

```
“/model/DUT/setup/InstrumentOptions”,”Save As”
```

where model, DUT, and setup are the actual model, DUT, and setup names.

An asterisk (*) next to an object (in this illustration) indicates that multiple objects or items with different names can be specified for that object. For example, a model may have many DUTs, but only one Parameter Set.

Tips:

- Objects (first argument) are case-sensitive and space-sensitive; use exact spellings shown throughout this documentation (spaces shown in the illustration at left are for readability only). Use the notations ../ and ../.. to indicate relative path for objects.
- Actions (second argument) are not sensitive to case or spaces.

Objects

IC-CAP

Specify using: "IC-CAP", "ic-cap" or "/"

Actions allowed

Change Directory (pg 899)
Clear Status Errors (pg 901)
Clear Status Output (pg 901)
Close Error Log (pg 903)
Close License Window (pg 904)
Close Output Log (pg 904)
Create Variable Table Variable (pg 906)
Debug Off (pg 923)
Diagnostics (pg 911)
Exit/Exit! (pg 921)
File Debug Off (pg 923)
File Debug On (pg 923)
License Status (pg 936)
New Model (pg 942)
Open Error Log (pg 944)
Open Hardware (pg 944)
Open Model (pg 946)
Open Output Log (pg 946)
Release License (pg 952)
Save All (pg 956)
Save All No Data (pg 956)
Screen Debug Off (pg 923)
Screen Debug On (pg 961)
Set Variable Table Value (pg 973)
Simulation Debugger (pg 975)
Status Window (pg 975)
Stop Simulator (pg 975)

Variables

Specify using: “<path>/Variables” where <path> is the path to a Model, DUT, or Setup, or the slash (/) only to specify the top-level IC-CAP object.

Actions allowed

Open (pg 943)
Print Via Server (pg 948)
Save As (pg 957)
Save As No Data (pg 957)
Send To Printer (pg 965)
Set Table Field Value (pg 970)

Examples:

```
iccap_func("/Variables","Save As")
iccap_func("/CGaas1/Variables","Save As")
iccap_func("/CGaas1/dc/Variables","Save As")
iccap_func("/myModel/myDut/mySetup/Variables","Save As")
```

GUI Items

Specify using: “GUIItems”

Actions allowed

Open (pg 943)
Save As (pg 957)

GUI Item

Specify using: “GUIItem”

Actions allowed

Add GUI (pg 894)
Close GUI (pg 903)
Close Single GUI (pg 904)
Copy (pg 905)
Destroy GUI (pg 910)
Destroy Single GUI (pg 911)
Display Modal GUI (pg 914)
Display Modeless GUI (pg 914)
Display Single Modal GUI (pg 915)
Display Single Modeless GUI (pg 916)
Set GUI Callbacks (pg 968)
Set GUI Options (pg 968)

Simulation Debugger

Specify using: “SimulationDebugger”

Actions allowed

Close (pg 902)
Manual Simulation (pg 940)
Save Command File (pg 958)
Save Input File (pg 958)
Save Output File (pg 958)
Simulation Debugger (pg 975)

Example

```
iccap_func("ic-cap","Simulation Debugger")
```

Hardware

Specify using: “Hardware”

Actions allowed

Add Active Instr (pg 893)
Add Interface File (pg 894)
Change Address (pg 898)
Clear Active List (pg 900)
Close Hardware (pg 904)
Delete Active Instr (pg 908)
Delete Interface File (pg 908)
Diagnostics (pg 912)
Disable Supplies (pg 913)
Display Found Instrs (pg 914)
Read from File (pg 949)
Rebuild Active List (pg 950)
Replace Interface File (pg 953)
Run Self-Tests (pg 956)
Write to File (pg 980)

HPIB Analyzer

Specify using: “Hardware/HPIBAnalyzer”

Actions allowed

Bus status (pg 897)
Change Interface File (pg 899)
Check Active Address (pg 900)
I-O_Lock (pg 926)
I-O_Reset (pg 927)
I-O_Screen Debug ON (pg 927)
I-O_Screen Debug OFF (pg 927)
I-O_Unlock (pg 928)
Listen Active Address (pg 937)
Macro File Execute (pg 937)
Macro File Specify (pg 939)
Print Read Buffer (pg 948)
Read String (pg 949)
Read String for Experts (pg 950)
Search for Instruments (pg 962)
Send Command Byte (pg 963)
Send, Receive, and Print (pg 965)
Send String (pg 965)
Serial Poll (pg 966)
Set Active Address (pg 966)
Set Speed (pg 969)
Set Timeout (pg 971)
Talk Active Address (pg 976)
Who Are You (pg 980)

MODEL

Specify using: “/<name>” where <name> is the name of the model

Actions allowed

Clear Data/Both (pg 900)
Clear Data/Measured (pg 900)
Clear Data/Simulated (pg 900)
Close All (pg 902)
Copy (pg 905)
Create Variable Table Variable (pg 906)
Delete (pg 907)
Display Plots (pg 915)
Edit (pg 919)
Export Dataset (pg 922)
Import Data (pg 931)
Import Measured Data (pg 932)
Import Measured or Simulated Data (pg 933)
Import Simulated Data (pg 933)
Import Simulated or Measured Data (pg 934)
Open (pg 943)
Open DUT (pg 944)
Open Macro (pg 945)
New DUT (pg 941)
New Macro (pg 942)
Refresh Dataset (pg 951)
Rename (pg 952)
Save As (pg 957)
Save As No Data (pg 957)
Save Extracted Deck (pg 958)
Set Variable Table Value (pg 973)
Stop Simulator (pg 975)

Circuit

Specify using: "/<model>/Circuit" where <model> is the name of a model

Actions allowed

Copy (pg 905)
Import Text (pg 935)
Open (pg 943)
Parse (pg 947)
Save As (pg 957)
Save As No Data (pg 957)

PlotOptimizer

Specify using: "/<model>/PlotOptimizer" where <model> is the name of a model

Actions allowed

Auto Set Min Max (pg 897)
Auto Set Optimize or Auto Set And Optimize (pg 897)
Clear Plot Optimizer (pg 901)
Clear Table or Clear Parameter Table (pg 901)
Disable All (pg 912)
Enable All (pg 920)
Optimize (pg 947)
Recall Parameters (pg 951)
Reset Min Max (pg 954)
Reset Option Table (pg 954)
Set Algorithm (pg 967)
Set Error (pg 967)
Set Table Field Value (pg 970)
Simulate All (pg 974)
Simulate Plot Inputs (pg 975)
Store Parameters (pg 976)
Tune Fast (pg 978)
Tune Slow (pg 978)
Undo Optim (pg 978)

PlotOptions

Specify using: "/<model>/PlotOptions" where <model> is the name of a model

Actions allowed Set Table Field Value (pg 970)

Example

```
iccap_func("dc/fgummel/PlotOptions","SetTableFieldValue",
           “<access name>”,"<value>")
```

where <access name> and <value> examples are listed in the following table:

Table 99 PlotOption Access Name and Value Examples

Description	Access Names	Values
Setting Trace Color on white	“On White[Data 0]”	"2" (gxvt color index)
Setting Trace Color on black	“On Black[Data 3]”	"4" (gxvt color index)
Setting Symbol	“Symbol[Data 0]”	“Circle”

Table 99 PlotOption Access Name and Value Examples (continued)

Description	Access Names	Values
Selecting Multicolor Curve setting	"Multicolor"	"Display all curves with the configured trace color", "Change color with every curve", "Change color with each 2nd order curve", "Change color with highest order curve"
Selecting Multicolor Curve color	"On White[Curve 0]"	"2" (gxvt color index)
Selecting Data Representation	"Measured Trace", "Simulated Trace", "Transform Result"	"Symbols Only", "Solid Line", "Dashed Line". Solid Line with Symbols"
Layout and background settings	"Show Title", "Show Title", "Show Header", “Show Footer", "Show Legend", "White Background", "Show Area Tools"	"Yes", "No", "Automatic"
Selecting font and size	"Font Type", "Font Size"	"Arial for CAE", "12"
Enable/Disable Annotation	"Enable Annotation"	"Yes", "No", "Automatic"
Annotation Location	"Annotation Location"	"Upper Left", etc.
Annotation text	"Annotation Text"	"W=10" or use an IC-CAP variable. Multiline text is available, each line must be separated by the string "\012"
Control Via PEL	"PEL Control"	"Yes", "No", "Automatic"
Specify annotation macro/transform	"PEL Transform"	<name path>
Specify when updating the annotation	"PEL Call Type"	"0" Only when plot is opened "1" Every time plot is refreshed

Parameter Set

Specify using: “/<model>/ParameterSet" where <model> is the name of a model

Actions allowed

Copy (pg 905)
Memory Recall (pg 941)
Memory Store (pg 941)
Open (pg 943)
ReadOnlyValues (pg 949)
Reset (pg 953)
Save As (pg 957)
Save As No Data (pg 957)

MACRO

Specify using: "/<model>/<macroName>" where <model> is the name of a model, and <macroName> is the name of a macro within that model

Actions allowed

Copy (pg 905)
Delete (pg 907)
Execute (pg 921)
Open (pg 943)
Rename (pg 952)
Save As (pg 957)
Save As No Data (pg 957)

DUT

Specify using: "/<model>/<DUT>" where <model> is the name of a model, and <DUT> is the name of a DUT within that model.

Actions allowed

Clear Data/Both (pg 900)
Clear Data/Measured (pg 900)
Clear Data/Simulated (pg 900)
Close All (pg 902)
Close Branch (pg 902)
Copy (pg 905)
Create Variable Table Variable (pg 906)
Delete (pg 907)
Display Plots (pg 915)
Export Dataset (pg 922)
Extract (pg 922)
Import Data (pg 931)
Import Measured Data (pg 932)
Import Measured or Simulated Data (pg 933)
Import Simulated Data (pg 933)
Import Simulated or Measured Data (pg 934)
Measure (pg 940)
New Setup (pg 943)
Open (pg 943)
Open Branch (pg 944)
Open Setup (pg 947)
Optimize (pg 947)
Rename (pg 952)
Save As (pg 957)
Save As No Data (pg 957)
Set Variable Table Value (pg 973)
Simulate (pg 974)

Test Circuit

Specify using: "/<model>/<dut>/TestCircuit" where <model> is the name of a model and <dut> is the name of a DUT within that model.

Actions allowed

Copy (pg 905)
Import Text (pg 935)
Open (pg 943)
Parse (pg 947)
Save As (pg 957)
Save As No Data (pg 957)

Device Parameter Set

Specify using: "/<model>/<dut>/DeviceParameterSet" where <model> is the name of a model and <dut> is the name of a DUT within that model.

Actions allowed

Copy (pg 905)
Memory Recall (pg 941)
Memory Store (pg 941)
Open (pg 943)
ReadOnlyValues (pg 949)
Reset (pg 953)
Save As (pg 957)
Save As No Data (pg 957)

SETUP

Specify using: "/<model>/<DUT>/<Setup>" where <model> is the name of a model, and <DUT> is the name of a DUT within that model, and <Setup> is a setup within that DUT.

Actions allowed

Calibrate (pg 898)
Clear Data/Both (pg 900)
Clear Data/Measured (pg 900)
Clear Data/Simulated (pg 900)
Close All (pg 902)
Copy (pg 905)
Create Variable Table Variable (pg 906)
Delete (pg 907)
Display Plots (pg 915)
Export Data Measured (pg 921)
Export Dataset (pg 922)
Export Data Simulated (pg 922)
Extract (pg 922)
Import Create (pg 928)
Import Create Header Only (pg 928)
Import Create Measured (pg 929)
Import Create Measured or Simulated (pg 929)
Import Create Simulated (pg 930)
Import Create Simulated or Measured (pg 930)
Import Data (pg 931)
Import Delete (pg 932)
Import Measured Data (pg 932)
Import Measured or Simulated Data (pg 933)
Import Simulated Data (pg 933)
Import Simulated or Measured Data (pg 934)
Measure (pg 940)
New Input (pg 942)
New Output (pg 942)
New Plot (pg 942)
New Transform (pg 942)
Open (pg 943)
Open Input (pg 945)
Open Output (pg 945)
Open Plot (pg 945)
Open Transform (pg 945)
Optimize (pg 947)
Rename (pg 952)
Save As (pg 957)
Save As No Data (pg 957)
Set Variable Table Value (pg 973)
Simulate (pg 974)

Instrument Options

Specify using: "/<model>/<DUT>/<Setup>/InstrumentOptions" where <model> is the name of a model, and <DUT> is the name of a DUT within that model, and <Setup> is a setup within that DUT.

Actions allowed

Open (pg 943)
Save As (pg 957)
Save As No Data (pg 957)

INPUT

Specify using: "/<model>/<DUT>/<Setup>/<Input>" where <model> is the name of a model, and <DUT> is the name of a DUT within that model, <Setup> is a setup within that DUT, and <Input> is the name of an input within the setup."

Actions allowed

Copy (pg 905)
Delete (pg 907)
Dump To Stdout (pg 917)
Edit (pg 919)
Open (pg 943)
Print Via Server (pg 948)
Redisplay (pg 951)
Rename (pg 952)
Save As (pg 957)
Save As No Data (pg 957)
Send To Printer (pg 965)
Set Table Field Value (pg 970)
View (pg 980)

OUTPUT

Specify using: "/<model>/<DUT>/<Setup>/<Output>" where <model> is the name of a model, and <DUT> is the name of a DUT within that model, <Setup> is a setup within that DUT, and <Output> is the name of an output within the setup.

Actions allowed

Copy (pg 905)
Delete (pg 907)
Dump To Stdout (pg 917)
Edit (pg 919)
Open (pg 943)
Print Via Server (pg 948)
Redisplay (pg 951)
Rename (pg 952)
Save As (pg 957)
Save As No Data (pg 957)
Send To Printer (pg 965)
Set Table Field Value (pg 970)
View (pg 980)

TRANSFORM

Specify using: "/<model>/<DUT>/<Setup>/<Transform>" where <model> is the name of a model, and <DUT> is the name of a DUT within that model, <Setup> is a setup within that DUT, and <Transform> is the name of a transform within the setup.

Actions allowed

Auto Set Min Max (pg 897)
Clear Table or Clear Parameter Table (pg 901)
Copy (pg 905)
Delete (pg 907)
Dump To Stdout (pg 917)
Execute (pg 921)
Open (pg 943)
Print Via Server (pg 948)
Recall Parameters (pg 951)
Redisplay (pg 951)
Rename (pg 952)
Reset Min Max (pg 954)
Reset Option Table (pg 954)
Save As (pg 957)

Save As No Data (pg 957)
Send To Printer (pg 965)
Set Algorithm (pg 967)
Set Error (pg 967)
Set Table Field Value (pg 970)
Store Parameters (pg 976)
Tune Fast (pg 978)
Tune Slow (pg 978)
Undo Optim (pg 978)
View (pg 980)

PLOT

Specify using: "/<model>/<DUT>/<Setup>/<Plot>" where <model> is the name of a model, and <DUT> is the name of a DUT within that model, <Setup> is a setup within that DUT, and <Plot> is the name of a plot within the setup.

Actions allowed

Add Global Region (pg 893)
Add Trace Region (pg 895)
Area Tools (pg 895)
Area Tools Off (pg 895)
Area Tools On (pg 896)
Autoconfigure or Autoconfigure And Enable (pg 896)
Autoscale (pg 896)
Close (pg 902)
Color (pg 905)
Copy (pg 905)
Copy to Clipboard (pg 906)
Copy to Variables (pg 906)
Data Markers (pg 907)
Delete (pg 907)
Delete Global Regions (pg 909)
Delete Trace Regions (pg 909)
Delete All User Regions (pg 910)
Legend Off (pg 936)
Legend On (pg 936)
Manual Rescale (pg 940)
Open (pg 943)
Open Plot Optimizer (pg 946)
Print Via Server (pg 948)
Rescale (pg 953)
Reset to Saved Options (pg 955)
Redisplay (pg 951)
Rename (pg 952)
Replot (pg 953)
Reset Global Region (pg 954)
Reset Trace Region (pg 955)
Save As (pg 957)
Save As No Data (pg 957)
Save Image (pg 958)
Scale Plot (pg 959)
Scale Plot Preview (pg 959)
Scale RI Plot (pg 960)

Delete User Region (pg 910)
Disable All Traces (pg 912)
Disable Plot (pg 913)
Disable Trace (pg 913)
Display Plots (pg 915)
Draw Diag Line (pg 916)
Dump To Plotter (pg 916)
Dump To Printer (pg 917)
Dump Via Server (pg 918)
Dump Via Server UI (pg 919)
Edit (pg 919)
Enable Plot (pg 920)
Exchange Black-White (pg 920)
Footer (pg 924)
Footer Off (pg 924)
Footer On (pg 925)
Full Page Plot (pg 925)
Header (pg 925)
Header Off (pg 925)
Header On (pg 926)
Legend (pg 935)
Scale RI Plot Preview (pg 960)
Select Error Region (pg 962)
Select Plot (pg 963)
Select Whole Plot (pg 963)
Send To Printer (pg 965)
Set Table Field Value (pg 970)
Set Target Vs Simulated (pg 971)
Set Trace As Both (pg 972)
Set User Region (pg 972)
Show Absolute Error (pg 973)
Show Relative Error (pg 974)
Text Annotation (pg 976)
Text Annotation Off (pg 977)
Text Annotation On (pg 977)
Toggle Zoom (pg 977)
Undo Zoom (pg 979)
Unselect All (pg 979)
Update Annotation (pg 979)
View (pg 980)
Zoom Plot (pg 981)

Actions

Actions can be used to automate many IC-CAP dialog buttons and menu picks. The following tables cross-reference GUI buttons or menu picks to their corresponding actions.

Table 100 Hardware Setup Window Cross-Reference

Button / Menu Pick	Action
Add Interface	"Add Interface File" on page 894
Add to List	"Add Active Instr" on page 893
Configure > Instrument Address	"Change Address" on page 898
Delete	"Delete Active Instr" on page 908
DeleteAll	"Clear Active List" on page 900
Delete Interface	"Delete Interface File" on page 908
File > Close Window	"Close Hardware" on page 904
File > Open	"Read from File" on page 949
File > Save	"Write to File" on page 980
Instruments > Display	"Display Found Instrs" on page 914
Instruments > Find	"Search for Instruments" on page 962
Instruments > Self Test	"Run Self-Tests" on page 956
Instruments > Usage	"Diagnostics" on page 912
Instruments > Zero Sources	"Disable Supplies" on page 913
Rebuild	"Rebuild Active List" on page 950
Tools > Address > Check	"Check Active Address" on page 900
Tools > Address > Listen	"Listen Active Address" on page 937
Tools > Address > Set	"Set Active Address" on page 966
Tools > Address > Talk	"Talk Active Address" on page 976
Tools > Address > Who Are You?	"Who Are You" on page 980

Table 100 Hardware Setup Window Cross-Reference (continued)

Button / Menu Pick	Action
Tools > Interface > Change	"Change Interface File" on page 899
Tools > Interface > Lock	"I-O_Lock" on page 926
Tools > Interface > Reset	"I-O_Reset" on page 927
Tools > Interface > Status	"Bus status" on page 897
Tools > Interface > Unlock	"I-O_Unlock" on page 928
Tools > Macros > Execute	"Macro File Execute" on page 937
Tools > Macros > Specify	"Macro File Specify" on page 939
Tools > Send Receive > Display String	"Print Read Buffer" on page 948
Tools > Send Receive > Read String for Experts	"Read String for Experts" on page 950
Tools > Send Receive > Receive String	"Read String" on page 949
Tools > Send Receive > Send Byte	"Send Command Byte" on page 963
Tools > Send Receive > Send Receive Display	"Send, Receive, and Print" on page 965
Tools > Send Receive > Send String	"Send String" on page 965
Tools > Serial Poll	"Serial Poll" on page 966
Tools > Settings > Timeout	"Set Timeout" on page 971
View > Screen Debug	"I-O_Screen Debug OFF" on page 927 "I-O_Screen Debug ON" on page 927

Table 101 License Status Cross-Reference

Button / Menu Pick	Action
OK	"Close License Window" on page 904
Release	"Release License" on page 952

Table 102 Main Window Cross-Reference

Button / Menu Pick	Action
File > Change Directory	"Change Directory" on page 899
Edit > Copy	"Copy" on page 905
Edit > Delete	"Delete" on page 907
File > Edit	"Edit" on page 919
File > Exit	"Exit/Exit!" on page 921
File > New	"New Model" on page 942
File > Open	"Open Model" on page 946
File > Save As	"Save All" on page 956 "Save All No Data" on page 956
Tools > Hardware Setup	"Open Hardware" on page 944
Tools > License Status	"License Status" on page 936
Tools > Options > Diagnostics	"Diagnostics" on page 911
Tools > Options > File Debug	"File Debug On" on page 923 "File/Screen Debug Off" on page 923
Tools > Options > Screen Debug	"File/Screen Debug Off" on page 923 "Screen Debug On" on page 961
Tools > Simulation Debugger	"Simulation Debugger" on page 975
Tools > Stop Simulator	"Stop Simulator" on page 975
Windows > Status Window	"Status Window" on page 975

Table 103 Model Window Cross-Reference

Button / Menu Pick	Action
Circuit folder, Import Text	"Import Text" on page 935
Circuit folder, Parse	"Parse" on page 947
Data > Plots > Display All	"Display Plots" on page 915

Table 103 Model Window Cross-Reference (continued)

Button / Menu Pick	Action
Duts / Setups folder, Add	"New DUT" on page 941 "New Setup" on page 943
DUTs / Setups, Extract / Optimize folder, Algorithm	"Set Algorithm" on page 967
DUTs / Setups, Extract / Optimize folder, Error	"Set Error" on page 967
DUTs / Setups, Extract / Optimize folder, Execute	"Execute" on page 921
DUTs / Setups, Extract / Optimize folder, Recall Par	"Recall Parameters" on page 951
DUTs / Setups, Extract / Optimize folder, Store Par	"Store Parameters" on page 976
DUTs / Setups, Extract / Optimize folder, Tune Fast	"Tune Fast" on page 978
DUTs / Setups, Extract / Optimize folder, Tune Slow	"Tune Slow" on page 978
DUTs / Setups, Extract / Optimize folder, Undo Optim	"Undo Optim" on page 978
DUTs / Setups, Extract / Optimize, Parameters folder, Autoset	"Auto Set Min Max" on page 897
DUTs / Setups, Extract / Optimize, Parameters folder, Clear Table	"Clear Table or Clear Parameter Table" on page 901
DUTs / Setups, Extract / Optimize, Parameters folder, Reset	"Reset Min Max" on page 954
DUTs / Setups, Instrument Options folder	"Set Instrument Option Value" on page 969
DUTs / Setups, Measure / Simulate folder, Calibrate	"Calibrate" on page 898
DUTs / Setups, Measure / Simulate folder, Clear > Measured, Simulated or Both Measured Simulated	"Clear Data / Simulated / Measured / Both" on page 900
DUTs / Setups, Measure / Simulate folder, Export Data	"Export Data Measured" on page 921 "Export Data Simulated" on page 922
DUTs / Setups, Measure / Simulate folder, Import Create	"Import Create" on page 928 "Import Create Header Only" on page 928 "Import Create Measured" on page 929 "Import Create Measured or Simulated" on page 929 "Import Create Simulated" on page 930 "Import Create Simulated or Measured" on page 930
DUTs / Setups, Measure / Simulate folder, Measure	"Measure" on page 940
DUTs / Setups, Measure / Simulate folder, Simulate	"Simulate" on page 974
DUTs / Setups, Measure / Simulate folder, View	"View" on page 980

Table 103 Model Window Cross-Reference (continued)

Button / Menu Pick	Action
DUTs / Setups, Measure / Simulate and Plots folder	"Set Table Field Value" on page 970
DUTs / Setups, Measure / Simulate folder, Input or Output, View, Dump to Stdout	"Dump To Stdout" on page 917
DUTs / Setups, Measure / Simulate folder, Input or Output, View, Print	"Dump To Plotter" on page 916 "Dump To Printer" on page 917 "Dump Via Server" on page 918 "Send To Printer" on page 965
DUTs / Setups, Measure / Simulate, Setup Variables folder, System Variables	"Create Variable Table Variable" on page 906
DUTs / Setups, Setup Variables folder	"Set Variable Table Value" on page 973
Edit > Cut Setup / Input	"Import Delete" on page 932
Extract > Active Setup or Active DUT	"Extract" on page 922
File > Close	"Close All" on page 902
File > Export Data	"Export Dataset" on page 922
File > Export Data > Extracted Deck	"Save Extracted Deck" on page 958
File > Import Data	"Import Data" on page 931 "Import Measured Data" on page 932 "Import Measured or Simulated Data" on page 933 "Import Simulated Data" on page 933 "Import Simulated or Measured Data" on page 934
File > Open	"Open" on page 943 "Open DUT" on page 944 "Open Setup" on page 947 "ReadOnlyValues" on page 949
File > Open (Input, Output, Transform, or Plot level selection)	"Open Input / Output / Transform / Plot" on page 945
File > Open (for Macro)	"Open Macro" on page 945
File > Print, (various dialogs) > Print	"Print Via Server" on page 948
File > Save As	"Save As" on page 957 "Save As No Data" on page 957
Macro folder, New	"New Macro" on page 942

Table 103 Model Window Cross-Reference (continued)

Button / Menu Pick	Action
Model Parameters folder, Memory Recall	"Memory Recall" on page 941
Model Parameters folder, Memory Store	"Memory Store" on page 941
Model Parameters folder, Reset	"Reset" on page 953
Optimize > Active Setup or Active DUT	"Optimize" on page 947
Tools > Plot Optimizer	"Open Plot Optimizer" on page 946
Tools > Refresh Last Dataset	"Refresh Dataset" on page 951
(various locations) > New	"New Input/Output/Transform/Plot" on page 942

Table 104 Plot Optimizer Window Cross-Reference

Button / Menu Pick	Action
Algorithm	"Set Algorithm" on page 967
Parameters folder, Clear Table	"Clear Table or Clear Parameter Table" on page 901
Error	"Set Error" on page 967
Options folder, Print Settings	"Dump To Plotter" on page 916 "Dump To Printer" on page 917 "Dump Via Server" on page 918 "Send To Printer" on page 965
File > Clear Plot Optimizer	"Clear Plot Optimizer" on page 901
File > Reset Option Table	"Reset Option Table" on page 954
File > Close	"Close" on page 902
Optimize > Tune Fast	"Tune Fast" on page 978
Optimize > Tune Slow	"Tune Slow" on page 978
Tools > Undo Optim	"Undo Optim" on page 978
Plots > Disable All	"Disable All" on page 912
Plots > Enable All	"Enable All" on page 920
Simulate > *plot name*	"Simulate Plot Inputs" on page 975

Table 104 Plot Optimizer Window Cross-Reference (continued)

Button / Menu Pick	Action
Simulate > Simulate All	"Simulate All" on page 974
Tools > AutoSet Min and Max	"Auto Set Min Max" on page 897
Tools > Recall Parameters	"Recall Parameters" on page 951
Tools > Reset Min and Max	"Reset Min Max" on page 954
Tools > Store Parameters	"Store Parameters" on page 976

Table 105 Plots Window Cross-Reference

Button / Menu Pick	Action
File > Close	"Close" on page 902
File > Print	"Dump Via Server UI" on page 919
File > Save Image	"Save Image" on page 958
Optimizer > Autoconfigure and Enable	"Autoconfigure or Autoconfigure And Enable" on page 896
Optimizer > Disable All Traces	"Disable All Traces" on page 912
Optimizer > Enable / Disable Plot	"Disable Plot" on page 913 "Enable Plot" on page 920
Optimizer > Global Region > Delete All	"Delete Global Regions" on page 909
Optimizer > Global Region > Reset	"Reset Global Region" on page 954
Optimizer > Open Optimizer	"Open Plot Optimizer" on page 946
Optimizer > *trace* > Disable	"Disable Trace" on page 913
Optimizer > *trace* > Set as Both Target and Simulated	"Set Trace As Both" on page 972
Optimizer > *trace* > Set as Target vs.	"Set Target Vs Simulated" on page 971
Optimizer > *trace* > Trace Optimizer Region > Add	"Add Trace Region" on page 895
Optimizer > *trace* > Trace Optimizer Region > DeleteAll	"Delete Trace Regions" on page 909
Optimizer > *trace* > Trace Optimizer Region > Reset	"Reset Trace Region" on page 955
Options > Autoscale	"Autoscale" on page 896

Table 105 Plots Window Cross-Reference (continued)

Button / Menu Pick	Action
Options > Copy to Clipboard	"Copy to Clipboard" on page 906
Options > Copy to Variables	"Copy to Variables" on page 906
Options > Draw Diag Line	"Draw Diag Line" on page 916
Options > Edit Definition	"Edit" on page 919
Options > Error > Select Error Region	"Select Error Region" on page 962
Options > Error > Select Whole Plot	"Select Whole Plot" on page 963
Options > Error > Show Absolute Error	"Show Absolute Error" on page 973
Options > Error > Show Relative Error	"Show Relative Error" on page 974
Options > Manual rescale	"Manual Rescale" on page 940 "Scale Plot/Scale Plot Preview" on page 959 "Scale RI Plot/Scale RI Plot Preview" on page 960
Options > Replot	"Replot" on page 953
Options > Rescale	"Rescale" on page 953
Options > Session Settings > Area Tools	"Area Tools" on page 895
Options > Session Settings > Color	"Color" on page 905
Options > Session Settings > Exchange Black-White	"Exchange Black-White" on page 920
Options > Session Settings > Footer	"Footer" on page 924
Options > Session Settings > Header	"Header" on page 925
Options > Session Settings > Legend	"Legend" on page 935
Options > Session Settings > Reset to Saved Options	"Reset to Saved Options" on page 955
Options > Session Settings > Text Annotation	"Text Annotation" on page 976
Options > Update Annotation	"Update Annotation" on page 979
Plots > Full Page Plot	"Full Page Plot" on page 925
Plots > Select Plot	"Select Plot" on page 963
Plots > Undo Zoom	"Undo Zoom" on page 979
Plots > Unselect All	"Unselect All" on page 979

Table 105 Plots Window Cross-Reference (continued)

Button / Menu Pick	Action
Plots > Zoom Plot	"Zoom Plot" on page 981

Table 106 Simulation Debugger Window Cross-Reference

Button / Menu Pick	Action
File > Close	"Close" on page 902
File > Manual Simulation	"Manual Simulation" on page 940
File > Save Command File File > Save Input File File > Save Output File	"Save Input/Command/Output File" on page 958

Table 107 Status Window Cross-Reference

Button / Menu Pick	Action
File > Clear > Errors	"Clear Status Errors" on page 901
File > Clear > Outputs	"Clear Status Output" on page 901
File > Close Error Log	"Close Error Log" on page 903
File > Close Output Log	"Close Output Log" on page 904
File > Open Error Log	"Open Error Log" on page 944
File > Open Output Log	"Open Output Log" on page 946

Table 108 System GUI Items Cross-Reference

Button / Menu Pick	Action
Add, Add Child	"Add GUI" on page 894
Close GUI	"Close GUI" on page 903
Close Single GUI	"Close Single GUI" on page 904
Destroy GUI	"Destroy GUI" on page 910

Table 108 System GUI Items Cross-Reference (continued)

Button / Menu Pick	Action
Destroy Single GUI	"Destroy Single GUI" on page 911
Display Modal GUI	"Display Modal GUI" on page 914
Display Modeless GUI	"Display Modeless GUI" on page 914
Display Single Modal GUI	"Display Single Modal GUI" on page 915
Display Single Modeless GUI	"Display Single Modeless GUI" on page 916
Set GUI Callbacks	"Set GUI Callbacks" on page 968
Set GUI Options	"Set GUI Options" on page 968

Add Active Instr

Automates the functionality of the “Add to List” button in the Hardware Setup window’s Instrument Library field.

Valid Objects Hardware

menu_func style command: "Add Active Instr"

Adds the instrument selected in the Instrument Library to the Instrument List. To execute this function manually, the user selects an instrument from the Instrument Library, then presses the "Add to List" button. This functionality is emulated in PEL by appending the instrument to be added in the format:

"library name.select code.address"

followed by "ok" to the end of the command string.

Where

library name is the instrument model number exactly as it is listed in the Instrument Library.
select code is the bus address (in decimal notation) of the GPIB card.
address is the address (in decimal notation) of instrument, as set on the instrument itself.

Example

```
iccap_func("Hardware","Add Active Instr","HP8510.7.16","ok")
```

Add Global Region

Automates the Optimizer > Global Region > Add menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Adds a global trace region without deleting existing global trace regions.

Example

```
iccap_func("./dc/fgummel/ibicvsve", "AddGlobalRegion",
            "0.6", "0.8", "-8", "-3")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AddGlobalRegion",
            "0.6", "0.8", "-8", "-3", "1")
```

See Also Delete Global Regions (pg 909)

Add GUI

Automates the functionality of the “Add” and “Add Child” buttons in the System GUI Items window.

Valid Objects GUI Item

menu_func style command: none

Adds Items to a GUI Items page or another GUI Item. You must specify the Item’s name and type code. To see the codes for all Item types, select the *Show Codes* button on the Properties dialog of a GUI Item.

Example

```
iccap_func("./GUIItems","Add GUI","ANewTable","TL")
iccap_func("./ANewTable","Add GUI","Button","PB")
```

See Also Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Add Interface File

Automates the functionality of the “Add Interface” button in the Hardware Setup window’s GPIB Interface field.

Valid Objects Hardware

menu_func style command: "Add Active Interface"

Adds a GPIB Interface to the system. If this function were executed manually, a dialog box would appear asking the user for the name of the interface to be added. This functionality is emulated in PEL by appending the interface to be added followed by “ok” to the end of the command string.

Example

```
iccap_func("Hardware","Add Interface File","hpib","ok")
```

Add Trace Region

Automates the Optimizer > *trace* > Trace Optimizer Region > Add menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Adds a trace optimizer region for the specified trace without deleting existing trace optimizer regions.

Example

```
iccap_func("./dc/fgummel/ibicvsve", "AddTraceRegion",
           "Y Data 0", "0.6", "0.8", "-8", "-3")
iccap_func("./dc/fgummel/bvsic", "AddTraceRegion",
           "Y Data 0", "1e-8", "1e-4", "20", "60")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AddTraceRegion",
            "Y Data 0", "1e-8", "1e-4", "20", "60", "1")
```

See Also Delete Trace Regions (pg 909)

Area Tools

Automates the Options > Session Settings > Area Tools menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Toggles the Area Tools on and off for the specified plot window.

Example

```
iccap_func("./dc/fgummel/bvsic", "AreaTools")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AreaTools", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AreaTools")
```

See Also Area Tools Off (pg 895), Area Tools On (pg 896)

Area Tools Off

Hides the Area Tools for the specified plot window.

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "AreaToolsOff")
```

```
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AreaToolsOff", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AreaToolsOff")
```

See Also Area Tools (pg 895), Area Tools On (pg 896)

Area Tools On

Displays the Area Tools for the specified plot window.

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "AreaToolsOn")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AreaToolsOn", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "AreaToolsOn")
```

See Also Area Tools (pg 895), Area Tools Off (pg 895)

Autoconfigure or Autoconfigure And Enable

Automates the Optimizer > Autoconfigure and Enable menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Automatically enables and configures the inputs in a Plot window.

Example

```
iccap_func("dc/fgummel/icibvsve", "Autoconfigure")
iccap_func("dc/fgummel/icibvsve", "AutoconfigureAndEnable")
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "Autoconfigure", "1")
! Apply to all plots in a Multiplot
iccap_func("dc/fgummel/my_multiplot", "Autoconfigure")
```

Autoscale

Automates the Options > Autoscale menu pick in a plot window

Valid Objects Plot

menu_func style command: “Replot Data”

Toggles whether the plot automatically rescales when the data changes.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg", "Autoscale")
! Specify plot number for Multiplot
iccap_func("/CGaas1/dc/igvg/my_multiplot", "Autoscale", "1")
! Apply to all plots in a Multiplot
iccap_func("/CGaas1/dc/igvg/my_multiplot", "Autoscale")
```

Auto Set Min Max

Automates the Tools > AutoSet Min Max menu pick in the Plot Optimizer window and the Auto Set button in the Extract/Optimize folder.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Sets minimum and maximum optimizer parameter values based on the value of the coefficient defined with the AUTOSET_COEFF variable. The default coefficient value is 5.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”Auto Set Min Max”)
iccap_func(“./PlotOptimizer”,”Auto Set Min Max”)
```

Auto Set Optimize or Auto Set And Optimize

Automates the Optimizer > Autoset Min/Max and Optimize menu pick in the Plot Optimizer window.

Valid Objects Plot Optimizer

menu_func style command: none

Sets minimum and maximum optimizer parameter values based on the value of the coefficient defined with the AUTOSET_COEFF variable then runs an optimization. The default coefficient value is 5.

Example

```
iccap_func(“./PlotOptimizer”,”AutoSetAndOptimize”)
```

Bus status

Automates the functionality of the “Tools/Interface/Status” menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Bus status"

Provides information on the status of the current interface including:

- Name
- Select Code
- Bus Address
- System Controller State
- Active Controller State
- Talker State
- Listener State
- SRQ State
- NDAC State

This information is displayed in the IC-CAP/Status window and, if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Bus status")
```

Calibrate

Automates the Measure/Simulate folder's Calibrate button.

Valid Objects Setup

menu_func style command: "Calibrate"

Performs calibration on the specified setup

Example

```
iccap_func("CGaas1/dc/igvg_0vs","Calibrate")
```

Change Address

Automates the functionality of the Instrument Address spin box in the dialog box displayed by the Configure button in the Instrument List in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: "Change Address"

Sets the address of the specified instrument. If this function were executed manually, the desired new address would be read from the spin box in the Configuration Dialog Box when the OK button was pushed. This functionality is emulated in PEL by appending the old GPIB name string in the format:
`"library name.select code.address"`

followed by "ok" and the new desired address followed by "ok" to the end of the command string.

Example

```
iccap_func("Hardware","Change Address",
           "HP3577.7.18","ok","19","ok")
```

Change Directory

Automates IC-CAP/Main File > Change Directory

Valid Objects IC-CAP

menu_func style command: “Utilities/Change Directory”

Prompts for the name of a new directory to use as the current working directory. The directory prompt can be anticipated by the third argument.

Example

```
iccap_func("ic-cap","Change Directory",
           "/users/me/my_other_work_dir")
```

Change Interface File

Automates the functionality of the Tools > Interface > Change menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Change Interface File"

Changes the currently active GPIB interface. All further commands of the GPIB Analyzer will be directed to this new interface. If this function were executed manually, a dialog box would appear asking the user for the name of the new interface. This functionality is emulated in PEL by appending the name of the new interface followed by "ok" to the end of the command string.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Change Interface File",
           "new_name","ok")
```

Check Active Address

Automates the functionality of the Tools > Address > Check menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Check Active Address"

This function sends a serial poll to the device at the currently active address as previously set by a call to “Set Active Address.” The result is displayed in the IC-CAP/Status window and, if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Set Active Address",
           "8","ok")
iccap_func("Hardware/HPIBAnalyzer","Check Active Address")
```

Clear Active List

Automates the functionality of the DeleteAll button in the Hardware Setup window’s Instrument List field.

Valid Objects Hardware

menu_func style command: "Clear Active List"

Removes all instruments in all setups from the Active Instrument List.

Example

```
iccap_func("Hardware","Clear Active List")
```

Clear Data / Simulated / Measured / Both

- Clear Data/Simulated
- Clear Data/Measured
- Clear Data/Both

Automates the Model Window's Data > Clear Active Setup Data functionality or the Clear button in the Measure/Simulate folder.

Valid Objects Model, DUT, Setup

menu_func style commands were the same.

Clears the specified type of data from the outputs and transforms of the named Model, named DUT, or named setup.

Examples

```
iccap_func("/CGaas1/dc/igvg_0vs","Clear Data/Simulated")
iccap_func("/CGaas1/dc","Clear Data/Measured")
iccap_func("/CGaas1","Clear Data/Both")
```

Clear Plot Optimizer

Automates the File > Clear Plot Optimizer menu pick in the Plot Optimizer window.

Valid Objects Plot Optimizer

menu_func style command: none

Disables all traces and regions in the plots, disables all open plots, and clears the Parameters table.

Example

```
iccap_func("./PlotOptimizer","Clear Plot Optimizer")
```

See Also Clear Table or Clear Parameter Table (pg 901)

Clear Status Errors

Clears Status window's Warnings/Errors.

Valid Objects IC-CAP

menu_func style command: none

Example

```
iccap_func("/","Clear Status Errors")
```

Clear Status Output

Clears Status window's IC-CAP Output.

Valid Objects IC-CAP

menu_func style command: none

Example

```
iccap_func("/","Clear Status Output")
```

Clear Table or Clear Parameter Table

Automates the Clear Table button on the Parameter folder in the Plot Optimizer window and in the Extract/Optimize folder.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Deletes all parameters and variables in the optimizer's parameter folder.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”Clear Table”)
iccap_func(“./PlotOptimizer”,”Clear Table”)
```

See Also Clear Plot Optimizer (pg 901)

Close

Automates the IC-CAP/Simulation Debugger or Plot window's File > Close functionality.

Valid Objects Simulation Debugger, Plot

menu_func style command: “Close”

Closes the Simulation Debugger or Plot window if open.

Example

```
iccap_func("Simulation Debugger","Close")
! closed Simulation Debugger
iccap_func("/npn/dc/fgummel/ibicvsve","Close")
!closes plot
```

Close All

Automates the Model window's File > Close functionality.

Valid Objects Model, DUT, Setup

menu_func style command: “Close All”

Closes the model window and all associated windows, or all plot windows within a named DUT or setup.

Example

```
iccap_func("/CGaas1","Close All")
! closes model and all children
iccap_func("/CGaas1/dc","Close All")
! closes all plots within DUT
```

Close Branch

Automates the action of closing a DUT on the DUTs/Setups tree.

Valid Objects DUT

menu_func style command: none

Closes a DUT on the DUTs/Setups tree. By default, if you fabricate new DUTs with iccap_func *Add DUT*, the branch will be in the open state. Use this iccap_func to close it.

Example

```
iccap_func(“/mymodel/mydut”,“Close Branch”)
```

See Also Open Branch (pg 944)

Close Error Log

Automates the IC-CAP/Status window’s Close Error Log functionality.

Valid Objects IC-CAP

menu_func style command: none

Closes the error log file.

Example

```
iccap_func("ic-cap","Close Error Log")
```

Close GUI

Automates closing an instance of a GUI item.

Valid Objects GUI Item

menu_func style command: none

Closes the named instance of a GUI item. Although no longer displayed, the GUI item still reacts to modifications to the variables page, etc.

Example

```
iccap_func("/mdl/dut/orSet/GUIName","Close GUI",
           "InstanceName")
```

See Also Add GUI (pg 894), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Close Hardware

Automates the functionality of the File > Close Window menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: none

This function closes the Hardware Setup window.

Example

```
iccap_func("Hardware","Close Hardware")
```

Close License Window

Automates the functionality of the OK button in the License Status window. The window must be currently displayed (either by a License Status call or by choosing Tools > License Status in the Main window).

Valid Objects IC-CAP

menu_func style command: none

This function closes the License Status window.

Example

```
iccap_func("IC-CAP","Close License Window")
```

Close Output Log

Automates the IC-CAP/Status window's Close Output Log functionality.

Valid Objects IC-CAP

menu_func style command: none

Closes the output log file.

Example

```
iccap_func("ic-cap","Close Output Log")
```

Close Single GUI

Automates closing a single displayed GUI item.

Valid Objects GUI Item

menu_func style command: none

Closes the displayed GUI item. Although no longer displayed, the GUI item still reacts to modifications to the variables page, etc.

Example

```
iccap_func("/mdl/dut/orSet/GUIName","Close Single GUI")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Color

Automates the Options > Session Settings > Color menu pick in a plot window.

Valid Objects Plot

Toggles between color and black and white. Each time you c all you either go to color or to black and white.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Color")
```

Copy

Automates copying an item to a new name, but does not permit undo or paste after completion.

Valid Objects Model, Macro, DUT, Setup, Input, Output, Transform, Plot, Circuit, Test Circuit, Parameter Set, Device Parameter Set, GUI Item.

menu_func style command: “Copy”

Prompts for the name of the copied item, or uses the optional third argument if provided. The name of the copied item is determined relative to the item being copied, not relative to the transform/macro being run. Whether prompted or supplying the optional third argument, the name of the copied item must name the item. Thus to copy item *item* to container *container*, you must specify the copied name as *container/item*, not simply *container*.

Example
```
iccap_func("/CGaas1","Copy","myCGaas1")
iccap_func("/CGaas1/extract","Copy","myCGaas1/extract2")
iccap_func("/mymodel/myGUI.subgui","Copy","newgui")
! creates /mymodel/myGUI.newgui
iccap_func("/mymodel/myGUI.subgui","Copy","./newGUI")
! creates /mymodel/newGUI (name relative to copied item)
```

Copy to Clipboard

Automates the Options > Copy to Clipboard menu pick in a plot window. This feature is only available for the PC version of IC-CAP.

Valid Objects Plot

menu_func style command: none

Example
```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Copy to
           Clipboard")
```

Copy to Variables

Automates the Options > Copy to Variables menu pick in a plot window.

Valid Objects Plot

menu_func style command: “Set Variables”

Sets X_HIGH, X_LOW, Y_HIGH, and Y_LOW if those variables exist somewhere that the plot can see them and if a box has been selected on the graph. This function is not available for the Multiplot window.

Example
```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Copy to
           Variables")
```

Create Variable Table Variable

Automates adding a new variable to a Variable table.

Valid Objects IC-CAP, Model, DUT, Setup

menu_func style command: none

Uses one anticipated argument to name the variable to add to the Variable table on the noted object. Note, if this variable already exists, no action is taken.

NOTE

You cannot directly refer to a newly created variable in the PEL program that created it. Indirect references such as lookup_var() and iccap_func with “Set Variable Table Value” will work.

Variable identification is handled when a PEL program is parsed. Assuming 'newVar' does not exist in any Variable table, the following code example treats newVar as a local variable:

```
iccap_func(".","CreateVariableTableVariable","newVar")
newVar=12
! newVar is local to PEL only, won't reference Variable table
```

However, if you run the same lines twice, the second time the iccap_func does nothing and newVar is identified in the Variable table before the program runs, and newVar **will** refer to the Variable table.

Examples

```
iccap_func("/npn","CreateVariableTableVariable",
           "newVariable")
```

See Also Set Table Field Value (pg 970), Set Variable Table Value (pg 973)

Data Markers

Automates the Options > Data Markers menu pick in a plot window

Valid Objects Plot

menu_func style command: “Line Number On Off”

Toggles whether Data Markers are displayed on the plot.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Data Markers")
```

Delete

Automates Edit > Delete (no Undo) menu selection

Valid Objects Model, Macro, DUT, Setup, Input, Output, Transform, Plot

menu_func style command: “Delete”

Deletes the named object from the system. No Undo

Example

```
iccap_func("/CGaas1","Delete")
```

Delete Active Instr

Automates the functionality of the Delete button in the Hardware Setup window's Instrument List field.

Valid Objects Hardware

menu_func style command: "Delete Active Instr"

Deletes the instrument selected in the Instrument List from the Active Instrument List. If this function were executed manually, the user would select the instrument in the Instrument List field and press the "Delete" button. This functionality is emulated in PEL by appending the instrument to be deleted in the format:

"library name.select code.address"

followed by "ok" to the end of the command string.

Where

library name is the instrument model number exactly as it is listed in the Instrument Library.
select code is the bus address (in decimal notation) of the GPIB card.
address is the address (in decimal notation) of instrument, as set on the instrument itself.

Example

```
iccap_func("Hardware","Delete Active Instr",
           "HP8510.7.16","ok")
```

Delete Interface File

Automates the functionality of the "Delete Interface" button in the Hardware Setup window's GPIB Interface field.

Valid Objects Hardware

menu_func style command: "Delete Active Interface"

Deletes a GPIB Interface from the system. If this function were executed manually, the user would select the interface to be delete from the GPIB Interface list and press the "Delete

Interface" button. This functionality is emulated in PEL by appending the interface name to be deleted followed by "ok" to the end of the command string.

Example

```
iccap_func("Hardware","Delete Interface File","hpib","ok")
```

Delete Global Regions

Automates the Optimizer > Global Region > Delete All menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Deletes all global trace regions.

Example

```
iccap_func("./dc/fgummel/ibicvsve", "DeleteGlobalRegions")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot",
            "DeleteGlobalRegions", "1")
```

See Also Add Global Region (pg 893)

Delete Trace Regions

Automates the Optimizer > *trace* > Trace Optimizer Region > DeleteAll menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Deletes all existing trace optimizer regions for the selected trace.

Example

```
iccap_func("./dc/fgummel/ibicvsve", "DeleteTraceRegions",
             "Y Data 0")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot",
            "DeleteTraceRegions", "Y Data 0", "1")
```

See Also Add Trace Region (pg 895)

Delete All User Regions

Deletes all user defined regions.

Valid Objects Plot

menu_func style command: none

Example
```
iccap_func("dc/fgummel/icibvsve", "DeleteAllUserRegions")
```

See Also Delete User Region (pg 910), Set User Region (pg 972)

Delete User Region

Deletes specified user defined region.

Valid Objects Plot

menu_func style command: none

Example
```
iccap_func("dc/fgummel/icibvsve", "DeleteUserRegion",
           "my_region_name")
```

See Also Delete All User Regions (pg 910), Set User Region (pg 972)

Destroy GUI

Automates closing an instance of a GUI item and frees the associated memory.

Valid Objects GUI Item

menu_func style command: none

Closes the named instance of a GUI item and frees the associated memory. The next Display needs to build the entire item again.

Example
```
iccap_func("/mdl/dut/orSet/GUIName","Destroy GUI",
           "InstanceName")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Destroy Single GUI

Automates closing a single displayed GUI item and frees the associated memory.

Valid Objects GUI Item

menu_func style command: none

Closes the displayed GUI item and frees the associated memory. The next Display needs to build the entire item again.

Example
```
iccap_func("/mdl/dut/orSet/GUIName","Destroy Single GUI")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Diagnostics

Automates functionality of IC-CAP/Main Tools > Options > Diagnostics.

Valid Objects IC-CAP

menu_func style command: “Utilities/Diagnostics”

Does a diagnostic check on most objects in the system. Reports on data structure integrity. Output is of the format:

```
Diagnostics check for <type> <name>:
   Errors listed here.
Diagnostics check for <type> <name>:
   Errors listed here.
.
.
.
```

If no errors are reported, IC-CAP is functioning normally.

Example
```
iccap_func("ic-cap","Diagnostics")
```

Diagnostics

Automates the functionality of the Instruments > Usage menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: "Diagnostics"

This command displays the usages of the instruments specified in the model file.

Example

```
iccap_func("Hardware","Diagnostics")
```

Disable All

Automates the Plots > Disable All menu pick in the Plot Optimizer window.

Valid Objects Setup, Transform

menu_func style command: none

Disables all open Plot windows in a model file.

Example

```
iccap_func(“./PlotOptimizer”,”DisableAll”)
```

Disable All Traces

Automates the Optimizer > Disable All Traces menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Disables all trace.

Example

```
iccap_func("dc/fgummel/icibvsve", "DisableAllTraces")
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "DisableAllTraces", "1")
```

Disable Plot

Automates the Optimizer > Enable/Disable Plot menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Disables the plot window.

Example

```
iccap_func("dc/fgummel/icibvsve", "DisablePlot")
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "DisablePlot", "1")
```

Disable Supplies

Automates the functionality of the Instruments > Zero Sources menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: "Disable Supplies"

This command sets the outputs of all signal sources found either by the "Rebuild Active List" function or as the result of a measurement.

Example

```
iccap_func("Hardware","Disable Supplies")
```

Disable Trace

Automates the Optimizer > *trace* > Disable menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Disables the selected trace.

Example

```
iccap_func("dc/fgummel/icibvsve", "DisableTrace", “Y Data 1”)
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "DisableTrace",
           "Y Data 1", "1")
```

Display Found Instrs

Automates the functionality of the Instruments > Display menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: "Display Found Instrs"

This command displays all the devices found on the bus either during the execution of the "Rebuild Active List" command or as the result of a measurement.

Example

```
iccap_func("Hardware","Display Found Instrs")
```

Display Modal GUI

Automates displaying a named instance of a modal GUI.

Valid Objects GUI Item

menu_func style command: none

Since the third argument is a unique name for that instance of the dialog, you can raise three identical dialogs if it makes sense to do so.

Example

```
iccap_func("/mdl/dut/orSet/GuiName","Display Modal GUI",
           "InstanceName")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Display Modeless GUI

Automates displaying a named instance of a modeless GUI.

Valid Objects GUI Item

menu_func style command: none

Since the third argument is a unique name for that instance of the dialog, you can raise three identical dialogs if it makes sense to do so.

Example

```
iccap_func("/mdl/dut/orSet/GuiName","Display Modeless GUI",
           "InstanceName")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Display Plots

Automates the Data > Plots > Display All functionality.

Valid Objects Model, DUT, Setup

menu_func style command: “Display Plots”

Displays all plots available in the named Model, named DUT, or named setup.

Examples:

```
iccap_func("/CGaas1/dc","Display Plots")
iccap_func("/CGaas1/dc/igvg_0vs","Display Plots")
iccap_func("/CGaas1","Display Plots")
```

Display Single Modal GUI

Automates displaying a single modal GUI item.

Valid Objects GUI Item

menu_func style command: none

Since a name is not required, you can only show the dialog once using this command. This is useful for callbacks—see the properties for the Wizard GUI Item's Cancel button in the gui_tutorial.mdl.

Example

```
iccap_func("/mdl/dut/orSet/GuiName","Display Single Modal
           GUI")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Display Single Modeless GUI

Automates displaying a single modeless GUI item.

Valid Objects GUI Item

menu_func style command: none

Since a name is not required, you can only show the dialog once using this command. This is useful for callbacks—see the properties for the Wizard GUI Item's Cancel button in the gui_tutorial.mdl.

Example

```
iccap_func("/mdl/dut/orSet/GuiName","Display Single Modeless
           GUI")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Set GUI Callbacks (pg 968), Set GUI Options (pg 968)

Draw Diag Line

Automates the Options > Draw Diag Line menu pick in a plot window

Valid Objects Plot

menu_func style command: “Draw Diag Line”

Draws a solid line along the diagonal. Acts as a toggle, each time you call you either draw it or take it down.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","DrawDiagLine")
! Specify plot number for Multiplot
iccap_func("/CGaas1/dc/igvg/my_multiplot","DrawDiagLine",
           "1")
```

Dump To Plotter

Provided to be compatible with Version 4.5 style of printing

Valid Objects Plot

menu_func style command: “Dump To Printer”

Prompts for the name of the command through which to pipe the HPGL file. May be anticipated by a third argument. Prints the graphical plot.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Dump To
           Plotter","lp -dmyprinter")
```

See Also Print Via Server (pg 948), Dump To Printer (pg 917), Dump Via Server (pg 918)

Dump To Printer

Provided to be compatible with 4.5 style of printing.

Valid Objects Plot

menu_func style command: “Dump To Printer”

Prompts for the name of the command through which to pipe the required file. May be anticipated by a third argument. Prints the graphical plot.

NOTE

The format of the file passed to the command will be PostScript. This is different from the 4.5 release. (Dump Via Server is recommended.)

If existing PEL code passes a command as an additional parameter, it must be modified to expect PostScript instead of the 4.5 formats.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Dump To
           Printer","lp -dmyprinter")
```

See Also Print Via Server (pg 948), Dump To Plotter (pg 916), Dump Via Server (pg 918)

Dump To Stdout

Automates the "Dump To Stdout" button on the 'View Data' window.

Valid Objects Input, Output, Transform

menu_func style command: “Dump To Stdout”

Writes the text that would go in the 'View Data' block out to the output window of the Status window. Useful if running a logfile of the output window and you want to monitor your automation.

Example

```
iccap_func("CGaas1/dc/igvg_0vs/vs","Dump To Stdout")
```

Dump Via Server

Automates printing to supported file types.

Valid Objects Plot

menu_func style command: none (see “Send to Printer”)

Provides functionality for the HPGL2 printing capability available in the File > Print dialog box. For the PC, this also provides functionality for the .emf file output accessed in the File > Print dialog box. Finally, it provides the capability to create a black and white postscript file. Note, this is for backward compatibility only and this black and white postscript file can only be printed via this command–there is no user interface access to generating such a postscript file.

This iccap_func() prompts with questions for additional arguments. Initially you are prompted “Print to a File?”

if you answer “Y”, you are prompted for a filename and then for the format

if you answer “N”, a failure is indicated since this option is not available starting with IC-CAP 2004.

Examples:

```
! following line creates an HPGL2 file
iccap_func("myPlot","Dump Via Server","Y","hpglfile.hgl",
           "HPGL2")
! following line creates a black & white postscript file
iccap_func("myPlot","Dump Via Server","Y","psfile.ps","PS")
! following line will create a .emf file on PC only
iccap_func("myPlot","Dump Via Server","Y","emffile.emf",
           "EMF")
```

See Also Send To Printer (pg 965), Dump To Printer (pg 917), Dump To Plotter (pg 916), and Variables PAPER (pg 777) and PLOT_SCALE_FACTOR (pg 777)

Dump Via Server UI

Automates a Plot window's File > Print functionality.

Valid Object Plot

Displays the Print dialog box for printing a graphical plot.

Example

```
iccap_func("myPlot","Dump Via Server UI")
```

See Also Print Via Server (pg 948)

Edit

Automates the IC-CAP/Main window's File > Restore functionality or an Input, Output, or Plot's Edit... functionality.

Valid Objects Model, Input, Output, Plot

menu_func style command: "Edit"

Opens the Model window for the specified model. For Inputs, Outputs, or Plots, opens the dialog box for editing the definition of that Input, Output, or Plot. You cannot use extra arguments to fill in the dialog box. For that functionality, use "Set Table Field Value" instead.

NOTE

The dialog box for editing the definition of an Input, Output, or Plot actually edits a temporary Input, Output, or Plot that is thrown away if the user clicks *Cancel*. If the user clicks *OK*, then the temporary Input, Output, or Plot is copied over the original Input, Output, or Plot. This changes the order of the plots and also closes any open plots. The user will have to reopen the plots or refresh a Multiplot.

You can use *iccap_find_children* to inspect the setup after a call to *Edit* to determine if the user changed the name of the edited setup. If the old name is no longer in the setup, then the new name will be the last item in the list. If the user clicked *Cancel*, the order will be unchanged.

Example

```
iccap_func("/CGaas1","Edit")
iccap_func("/npn/dc/fgummel/bvsic","Edit")
iccap_func("/npn/dc/fgummel/ic","Edit")
iccap_func("/npn/dc/fgummel/vc","Edit")
```

Enable All

Automates the Plots > Enable All menu pick in the Plot Optimizer window.

Valid Objects Plot Optimizer

menu_func style command: none

Enables all open Plot windows in a model file.

Example

```
iccap_func(“./PlotOptimizer”,”Enable All”)
```

Enable Plot

Automates the Optimizer > Enable/Disable Plot menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Enables the plot window. Enabling the plot window synchronizes it with the Plot Optimizer window.

Example

```
iccap_func("dc/fgummel/icibvsve", "EnablePlot")
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "EnablePlot", "1")
! Apply to all plots in a Multiplot
iccap_func("dc/fgummel/my_multiplot", "EnablePlot")
```

Exchange Black-White

Automates the Options > Session Settings > Exchange Black-White menu pick in a plot window.

Valid Objects Plot

menu_func style command: “Exchange Blk Wht”

Toggles the background color of the plot from black to white.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Exchange
           Black-White")
```

Execute

Automates the Execute button on the Macro or Extract/Optimize Page.

Valid Objects Macro, Transform

menu_func style command: “Execute” for macros and “Perform Transform” for transforms

Executes the named macro or transform.

Example

```
iccap_func("/CGaas1/extract","Execute")
iccap_func("/CGaas1/dc/igvg_0vs/rf_off","Execute")
```

NOTE If the macro contains a LINPUT statement, which prompts for user input, you can include the desired responses as additional arguments in the iccap_func statement.

Exit / Exit!

- Exit
- Exit!

Automates the IC-CAP/Main window’s File > Exit functionality.

Valid Objects IC-CAP

menu_func style command: “Exit/Exit IC-CAP” which maps to the new “Exit” form

Shuts down the current IC-CAP session.

- "Exit" will prompt the user to save files before exiting
- "Exit!" exits with no questions asked

Example

```
iccap_func("ic-cap","Exit")
iccap_func("ic-cap","Exit!")
```

Export Data Measured

Automates the Export Data button in the Measure/Simulate folder.

Valid Objects Setup

menu_func style command: none

Prompts for the name of the file to export the measured data to, or uses the optional third argument if provided. (No provision is made for exporting transforms with this iccap_func statement.)

Example

```
iccap_func(“/spar_vs_temp/ac/spar_vs_temp”,”Export Data
           Measured”,”my_file.mdm”)
```

Export Dataset

Automates the Model window’s File > Export Data menu pick functionality.

Valid Objects Model, DUT, Setup

Exports the data to a dataset file (*.ds) in the specified path. If the optional third argument is not specified, prompts for the full path and file name.

Example

```
iccap_func("/CGaas1","Export Dataset",
           ”/tmp/data/my_dataset.ds”)
iccap_func("/CGaas1/dc","Export Dataset",
           ”/tmp/data/my_dataset.ds”)
iccap_func("/CGaas1/dc/igvg_0vs","Export Dataset",
           ”/tmp/data/my_dataset.ds”)
```

See Also Refresh Dataset (pg 951)

Export Data Simulated

Automates the Export Data button in the Measure/Simulate folder.

Valid Objects Setup

menu_func style command: none

Prompts for the name of the file to export the simulated data to, or uses the optional third argument if provided. (No provision is made for exporting transforms with this iccap_func statement.)

Example

```
iccap_func(“/spar_vs_temp/ac/spar_vs_temp”,”Export Data
           Simulated”,”my_file.mdm”)
```

Extract

Automates the Extract menu picks.

Valid Objects DUT, Setup

menu_func style command: “Extract”

Performs Extraction Transforms on all setups within named DUT or within named setup.

Example

```
iccap_func("/CGaas1/dc","Extract")
iccap_func("/CGaas1/dc/igvg_0vs","Extract")
```

File Debug On

Automates functionality of IC-CAP/Main Tools > Options > File Debug.

Valid Objects IC-CAP

menu_func style command: “Utilities/File Debug On”

Logs most debug information to $HOME/.icdebug. Also prints certain information only to the Status window.

NOTE File Debug On automatically turns Screen Debug Off.

Example

```
iccap_func("ic-cap","File Debug On")
```

See Also Debug Off (pg 923), File Debug Off (pg 923)

File / Screen Debug Off

- File Debug Off
- Screen Debug Off
- Debug Off

Automates functionality of IC-CAP/Main Tools > Options > File Debug and IC-CAP/Main Tools > Options > Screen Debug by effectively turning the toggles off.

Valid Objects IC-CAP

menu_func style command: “Utilities/Debug Off”

"File Debug Off", "Screen Debug Off", and "Debug Off" All have the same effect. They halt logging of data either to the screen or file.

NOTE "File Debug Off" will halt Screen Debug if it was on.

Example
```
iccap_func("ic-cap","Debug Off")
```

See Also File Debug On (pg 923), Screen Debug On (pg 961)

Footer

Automates the Options > Session Settings > Footer menu pick in a plot window

Valid Objects Plot

Toggles the footer text on and off for the specified plot. If Show Absolute Error or Show Relative Error is turned on, the error is displayed in the footer area and the footer text is turned off.

Example
```
iccap_func("./dc/fgummel/bvsic", "Footer")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "Footer", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "Footer")
```

See Also Footer Off (pg 924), Footer On (pg 925), Show Absolute Error (pg 973), Show Relative Error (pg 974)

Footer Off

Turns off the footer text for the specified plot.

Valid Objects Plot

Example
```
iccap_func("./dc/fgummel/bvsic", "FooterOff")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "FooterOff", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "FooterOff")
```

See Also Footer (pg 924), Footer On (pg 925)

Footer On

Turns on the footer text for the specified plot

Valid Objects Plot

Example

```
iccap_func("./dc/fgummel/bvsic", "FooterOn")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "FooterOn", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "FooterOn")
```

See Also Footer (pg 924), Footer Off (pg 924)

Full Page Plot

Automates the Plots > Full Page Plot menu pick in a Multiplot window

Valid Objects Plot

In the Multiplot window, displays only the specified plot and hides all other plots. Use Undo Zoom to display all plots.

Example

```
iccap_func("./dc/fgummel/my_multiplot", "FullPagePlot", "1")
```

See Also Toggle Zoom (pg 977), Zoom Plot (pg 981), Undo Zoom (pg 979)

Header

Automates the Options > Session Settings > Header menu pick in a plot window

Valid Objects Plot

Toggles the header text on and off for the specified plot.

Example

```
iccap_func("./dc/fgummel/bvsic", "Header")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "Header", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "Header")
```

See Also Header Off (pg 925), Header On (pg 926)

Header Off

Turns on the header text for the specified plot

Valid Objects Plot

Example
```
iccap_func("./dc/fgummel/bvsic", "HeaderOff")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "HeaderOff", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "HeaderOff")
```

See Also Header (pg 925), Header On (pg 926)

Header On

Turns on the header text for the specified plot

Valid Objects Plot

Example
```
iccap_func("./dc/fgummel/bvsic", "HeaderOn")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "HeaderOn", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "HeaderOn")
```

See Also Header (pg 925), Header Off (pg 925)

I-O_Lock

Automates the functionality of the Tools > Interface > Lock menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "I-O_Lock"

Because the GPIB allows multiple sessions on the same device or interface, the action of opening does not mean the user has exclusive use. In some cases, the user might not want others to have access to the devices on the bus or interface while he is using it. In such cases, the interface should be locked, which restricts other device and interface sessions from accessing it. This function sends a lock command to the currently active interface.

Example
```
iccap_func("Hardware/HPIBAnalyzer","I-O_Lock")
```

I-O_Reset

Automates the functionality of the Tools > Interface > Reset menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func type command: "I-O_Reset"

This function sends a reset command to the currently active interface.

Example

```
iccap_func("Hardware/HPIBAnalyzer","I-O_Reset")
```

I-O_Screen Debug OFF

Automates the functionality of the View > Screen Debug menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "I-O_Screen Debug OFF"

This command turns off the IC-CAP GPIB debugger and removes the check mark from the menu item.

Example

```
iccap_func("Hardware/HPIBAnalyzer","I-O_Screen Debugger
            OFF")
```

I-O_Screen Debug ON

Automates the functionality of the View > Screen Debug menu pick in the Hardware Setup window. This menu item is a toggle. If a checkmark appears next to the it, the debugger is ON; otherwise, it is OFF.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "I-O_Screen Debug ON"

This command turns on the IC-CAP GPIB debugger which produces detailed status messages as the various operations are executed. This information is displayed in the IC-CAP/Status window and, if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","I-O_Screen Debug ON")
```

I-O_Unlock

Automates the functionality of the Tools > Interface > Unlock menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIB Analyzer

menu_func style command: "I-O_Unlock"

This function sends a unlock command to the currently active interface.

Example

```
iccap_func("Hardware/HPIBAnalyzer","I-O_Unlock")
```

Import Create

Reads named MDM file, removes existing information from setup, then imports all header information and data from the file to the setup object. If third argument is omitted, you will be prompted for a filename.

Valid Objects Setup

menu_func style command: none

Data is read into the measured array for outputs of type M or B and into the simulated array for outputs of type S. This is identical to Import Create Measured or Simulated.

Example

```
iccap_func("/myModel/myDut/mySetup","Import Create",
           "/tmp/tmpfile.mdm")
iccap_func("/myModel/myDut/mySetup","Import Create")
           ! prompt user
```

See Also Import Create Header Only (pg 928), Import Create Measured (pg 929), Import Create Simulated (pg 930), Import Create Simulated or Measured (pg 930)

Import Create Header Only

Reads the header of the MDM file and creates or modifies the named setup to exactly match the shape of the data contained in the MDM file. No data is imported. If third argument is omitted, you will be prompted for a filename.

Valid Objects Setup

menu_func style command: none

Example

```
iccap_func("/myModel/myDut/mySetup","Import Create Header
           Only","/tmp/tmpfile.mdm")
iccap_func("/myModel/myDut/mySetup","Import Create Header
           Only") ! prompt user
```

See Also Import Create (pg 928), Import Create Measured (pg 929), Import Create Simulated (pg 930), Import Create Measured or Simulated (pg 929), Import Create Simulated or Measured (pg 930)

Import Create Measured

Reads named MDM file, removes existing information from setup, then imports all header information and data from the file to the setup object. If third argument is omitted, you will be prompted for a filename.

Valid Objects Setup

menu_func style command: none

Data is read into the measured array for outputs of type M or B and no data is read into the simulated array for outputs of type S.

Example

```
iccap_func("/myModel/myDut/mySetup","Import Create
           Measured","/tmp/tmpfile.mdm")
iccap_func("/myModel/myDut/mySetup","Import Create
           Measured")! prompt user
```

See Also Import Create (pg 928), Import Create Header Only (pg 928), Import Create Simulated (pg 930), Import Create Measured or Simulated (pg 929), Import Create Simulated or Measured (pg 930)

Import Create Measured or Simulated

Reads named MDM file, removes existing information from setup, then imports all header information and data from the file to the setup object. If third argument is omitted, you will be prompted for a filename.

Valid Objects Setup

menu_func style command: none

Data is read into the measured array for outputs type M or B and into the simulated array for outputs type S. This is identical to Import Create.

Example

```
iccap_func("/myModel/myDut/mySetup","Import Create Measured
          or Simulated","/tmp/tmpfile.mdm")
iccap_func("/myModel/myDut/mySetup","Import Create Measured
          or Simulated") ! prompt user
```

See Also Import Create Header Only (pg 928), Import Create Measured (pg 929), Import Create Simulated (pg 930), Import Create Simulated or Measured (pg 930)

Import Create Simulated

Reads named MDM file, removes existing information from setup, then imports all header information and data from the file to the setup object. If third argument is omitted, you will be prompted for a filename.

Valid Objects Setup

menu_func style command: none

Data is read into the simulated array for outputs type S or B and no data is read into the measured array for outputs of type M.

Example

```
iccap_func("/myModel/myDut/mySetup","Import Create
          Simulated","/tmp/tmpfile.mdm")
iccap_func("/myModel/myDut/mySetup","Import Create
          Simulated") ! prompt user
```

See Also Import Create (pg 928), Import Create Header Only (pg 928), Import Create Measured (pg 929), Import Create Measured or Simulated (pg 929), Import Create Simulated or Measured (pg 930)

Import Create Simulated or Measured

Reads named MDM file, removes existing information from setup, then imports all header information and data from the file to the setup object. If third argument is omitted, you will be prompted for a filename.

Valid Objects Setup

menu_func style command: none

Data is read into the simulated array for outputs of type S or B and into the measured array for outputs of type M.

Example

```
iccap_func("/myModel/myDut/mySetup","Import Create Simulated
           or Measured","/tmp/tmpfile.mdm")
iccap_func("/myModel/myDut/mySetup","Import Create Simulated
           or Measured") ! prompt user
```

See Also Import Create (pg 928), Import Create Header Only (pg 928), Import Create Measured (pg 929), Import Create Simulated (pg 930), Import Create Measured or Simulated (pg 929)

Import Data

Automates the Model window's File > Import Data > Active Setup, All Setups in Active DUT, or All DUTs in a Model menu pick.

Valid Objects Model, DUT, Setup

menu_func style command: none

For Model and DUT, MDM filenames are specified in MDM_FILE_PATH and MDM_FILE_NAME in the setups contained by the DUT or Model. For calls to Setup objects, either specify the name in the 3rd argument or you will be prompted for a filename.

Data is read into the measured array for outputs type M or B and into the simulated array for outputs type S. This is identical to Import Measured or Simulated Data.

Example

```
iccap_func(“/CGaas1”,“Import Data”)
! Imports data to all DUTs in a model
iccap_func(“/CGaas1/dc”,“Import Data”)
! Imports data to all Setups in a DUT
iccap_func(“/CGaas1/dc/igvg_0vs”,“Import Data”)
! Imports data to a single setup, prompts user
iccap_func(“/CGaas1/dc/igvg_0vs”,“Import Data”,”tmp.mdm”)
! Imports data to a single setup
```

See Also Import Measured Data (pg 932), Import Measured or Simulated Data (pg 933), Import Simulated Data (pg 933), Import Simulated or Measured Data (pg 934)

Import Delete

Deletes inputs and outputs from the named setup.

Valid Objects Setup

menu_func style command: none

Example

```
iccap_func("/CGaas1/dc/igvg_0vs","Import Delete")
```

Import Measured Data

Automates the Model window's File > Import Data > Active Setup, All Setups in Active DUT, or All DUTs in a Model menu pick and selects Measured only.

Valid Objects Model, DUT, Setup

menu_func style command: none

For Model and DUT, MDM filenames are specified in MDM_FILE_PATH and MDM_FILE_NAME in the setups contained by the DUT or Model. For calls to Setup objects, either specify the name in the 3rd argument or you will be prompted for a filename.

Data is read into the measured array for outputs of type M or B and no data is read into the simulated array for outputs of type S.

Example

```
iccap_func(“/CGaas1”,“Import Measured Data”)
! Imports measured data to all DUTs in a model
iccap_func(“/CGaas1/dc”,“Import Measured Data”)
! Imports measured data to all Setups in a DUT
iccap_func(“/CGaas1/dc/igvg_0vs”,“Import Measured Data”)
! Imports measured data to a single setup and prompts user
iccap_func(“/CGaas1/dc/igvg_0vs”,“Import Measured
           Data”,”tmp.mdm”)
! Imports measured data to a single setup
```

See Also Import Data (pg 931), Import Measured or Simulated Data (pg 933), Import Simulated Data (pg 933), Import Simulated or Measured Data (pg 934)

Import Measured or Simulated Data

Automates the Model window's File > Import Data > Active Setup, All Setups in Active DUT, or All DUTs in a Model menu pick and selects Measured if available, otherwise Simulated.

Valid Objects Model, DUT, Setup

menu_func style command: none

For Model and DUT, MDM filenames are specified in MDM_FILE_PATH and MDM_FILE_NAME in the setups contained by the DUT or Model. For calls to Setup objects, either specify the name in the 3rd argument or you will be prompted for a filename.

Data is read into the measured array for outputs type M or B and into the simulated array for outputs type S. This is identical to Import Data.

Example

```
iccap_func("/CGaas1","Import Measured or Simulated Data")
! Imports measured data if available, otherwise simulated
! data to all DUTs in a model
iccap_func("/CGaas1/dc","Import Measured or Simulated Data")
! Imports measured data if available, otherwise simulated
! data to all Setups in a DUT
iccap_func("/CGaas1/dc/igvg_0vs","Import Measured or
           Simulated Data")
! Imports measured data if available, otherwise simulated
! data to a single setup and prompts user
iccap_func("/CGaas1/dc/igvg_0vs","Import Measured or
           Simulated Data","tmp.mdm")
! Imports measured data if available, otherwise simulated
! data to a single setup
```

See Also Import Data (pg 931), Import Measured Data (pg 932), Import Simulated Data (pg 933), Import Simulated or Measured Data (pg 934)

Import Simulated Data

Automates the Model window's File > Import Data > Active Setup, All Setups in Active DUT, or All DUTs in a Model menu pick and selects Simulated only.

Valid Objects Model, DUT, Setup

menu_func style command: none

For Model and DUT, MDM filenames are specified in MDM_FILE_PATH and MDM_FILE_NAME in the setups contained by the DUT or Model. For calls to Setup objects, either specify the name in the 3rd argument or you will be prompted for a filename.

Data is read into the simulated array for outputs type S or B and no data is read into the measured array for outputs of type M.

Example

```
iccap_func("/CGaas1","Import Simulated Data")
! Imports simulated data to all DUTs in a model
iccap_func("/CGaas1/dc","Import Simulated Data")
! Imports simulated data to all Setups in a DUT
iccap_func("/CGaas1/dc/igvg_0vs","Import Simulated Data")
! Imports simulated data to a single setup and prompts user
iccap_func("/CGaas1/dc/igvg_0vs","Import Simulated
          Data","tmp.mdm")
! Imports simulated data to a single setup
```

See Also Import Data (pg 931), Import Measured Data (pg 932), Import Measured or Simulated Data (pg 933), Import Simulated or Measured Data (pg 934)

Import Simulated or Measured Data

Automates the Model window's File > Import Data > Active Setup, All Setups in Active DUT, or All DUTs in a Model menu pick and selects Simulated if available, otherwise Measured.

Valid Objects Model, DUT, Setup

menu_func style command: none

For Model and DUT, MDM filenames are specified in MDM_FILE_PATH and MDM_FILE_NAME in the setups contained by the DUT or Model. For calls to Setup objects, either specify the name in the 3rd argument or you will be prompted for a filename.

Data is read into the simulated array for outputs of type S or B and into the measured array for outputs of type M.

Example

```
iccap_func("/CGaas1","Import Simulated or Measured Data")
! Imports simulated data if available, otherwise measured
! data to all DUTs in a model
iccap_func("/CGaas1/dc","Import Simulated or Measured Data")
! Imports simulated data if available, otherwise measured
```

```
! data to all Setups in a DUT
iccap_func(“/CGaas1/dc/igvg_0vs”,“Import Simulated or
           Measured Data”)
! Imports simulated data if available, otherwise measured
! data to a single setup and prompts user
iccap_func(“/CGaas1/dc/igvg_0vs”,“Import Simulated or
           Measured Data”,”tmp.mdm”)
! Imports simulated data if available, otherwise measured
! data to a single setup
```

See Also Import Data (pg 931), Import Measured Data (pg 932), Import Measured or Simulated Data (pg 933), Import Simulated Data (pg 933)

Import Text

Automates the "Import Text..." button in the Circuit folder.

Valid Objects Circuit, Test Circuit

menu_func style command: “Read Netlist”

Prompts for the name of a file from which to read text. Places all text in the Circuit folder. Automatically performs Parse. An optional third argument may be specified to name the file.

Example

```
iccap_func("/CGaas1/Circuit","Import Text","mycirc.deck")
iccap_func("/CGaas1/dc/TestCircuit","Import Text",
           "mycirc.deck")
```

Legend

Automates the Options > Session Settings > Legend menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Toggles the legend on and off for the specified plot.

Example

```
iccap_func("./dc/fgummel/bvsic", "Legend")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "Legend", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "Legend")
```

See Also Legend Off (pg 936), Legend On (pg 936)

Legend Off

Turns off the legend for the specified plot

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "LegendOff")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "LegendOff", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "LegendOff")
```

See Also Legend (pg 935), Legend On (pg 936)

Legend On

Turns on the legend for the specified plot

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "LegendOn")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "LegendOn", "1")
! Apply to all plots in a Multiplot
iccap_func("./dc/fgummel/my_multiplot", "LegendOn")
```

See Also Legend (pg 935), Legend Off (pg 936)

License Status

Brings up the same dialog that IC-CAP/Main Tools > License Status does.

Valid Objects IC-CAP

menu_func style command: “Utilities/Available Codewords”

Launches the 'License Status' dialog. However, this cannot be modified while PEL is still running. This iccap_func is useful only for informational purposes while the macro is running.

Example

```
iccap_func("ic-cap","License Status")
```

Listen Active Address

Automates the functionality of the Tools > Address > Listen menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Listen Active Address"

This function sends a LISTEN command to the device at the currently active address. The result is displayed in the IC-CAP/Status window and, if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Listen Active Address")
```

Macro File Execute

Automates the functionality of the Tools > Macros > Execute menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Macro File Execute"

This command executes the IC-CAP GPIB macro file name saved by the "Macro File Specify" command.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Marco File Execute")
//============================================================
//
// IC-CAP GPIB Analyzer macro command file description:
//
//============================================================
```

- Macro command files are read by the GPIB Analyzer and lines in the files execute actions, one action per line.
- Blank lines, or lines with only white spaces are ignored.
- Some lines are sent, others are 'directives'
- In any line, leading white spaces are ignored
- If, after optional leading white spaces, the directive character is seen, then that line is considered a directive. The dollar sign ($) is the directive character
- If the first non-white character does not indicate directive, then this character and all subsequent characters in the line are sent to the active address

- There is a means to send control characters, and this is the only means to affix terminators

  \b \r \n \0 \f \t \v \\ \<any other char>

  will first be converted to control characters or otherwise: backspace, CR, newline(=linefeed), null, formfeed, tab, vertical tab, backslash, <any other char>, respectively. \<any other char> behaves as a non-operation—it causes <any other char> to be sent. Note that a backslash and the directive char can always be sent, if preceded by backslash.
- Directives have a single command character (not case sensitive) following the Dollar sign ($) and may have trailing argument(s). White spaces between the command character and 1st argument are optional. Any characters on a line following the 'directive [arguments]' are ignored. This allows you to add comments following directive statements as desired.
- The directives are shown next:

$c	indicates current line is a comment
$r	reads into the read buffer
$a2	sets the active address (2 in this case)
$w3	wait for 3 seconds; if argument absent, default of ~2 chosen
$p	prints the contents of the read buffer
$m	message panel—user can indicate stop or continue; system will append the words "; want to continue?" to the characters that follow $m on the command line.
$n	print something to the Output panel IC-CAP/Status window and in the Hardware Setup window Status panel, if visible.
$s	serial poll of the device at the active address. If an integer parameter is present, then it is a serial poll mask, and the program will loop until <poll result> AND <integer mask> is non-zero, i.e., a desired 'bit' is set; if mask is negative, it loops until a mask-specified bit is clear.

$i	'call' another file and execute the macros in it. It should take the form: $i /users/icuser/macrofile.

An example of a legal macro file:

$c	this is an example IC-CAP GPIB Analyzer macro file ...
$a 16	active address = 16
$c	send request for instrument ID string:
*IDN?\n	
$r	read answer back
$p	print it
RST\n	
$w2	wait 2 seconds after sending RST to instrument
$c	next will open window, and ask:
$c	'Will now call other_macro_file; want to continue?'
$m	Will now call other_macro_file
$i	/icecap/other_macro_file 'call' another macro file
RST\n	
$w2	wait 2 seconds after sending RST to instrument

Macro File Specify

Automates the functionality of the Tools > Macros > Specify menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Macro File Specify"

This function saves the name of an IC-CAP GPIB Macro file to be executed later. If this menu pick were done manually, a dialog box would pop up requesting the name of the macro file. This functionality is emulated in PEL by appending the name of the file desired and "ok" to the command string.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Marco File Specify","
            ../mdl/bus_analyzer_macro.mac","OK")
```

Manual Rescale

Automates the Options > Manual rescale menu pick of a plot window.

NOTE This function is included for backward compatibility only. We recommend that you use Plot Scale. See “Scale Plot/Scale Plot Preview” on page 959.

Valid Objects Plot

menu_func style command: none

Adjusts the axes’ scales to values entered in statement. Scale values are entered in the order
X-min, Y-min, X-max, Y-max.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/ig_vs_vg","ManualRescale"
            ,”-2,0,0.1,0.01”)
```

Manual Simulation

Automates the IC-CAP/Simulation Debugger File > Manual Simulation functionality.

Valid Objects Simulation Debugger

menu_func style command: “Manual Simulate”

Performs a manual simulation on the last simulation run. Simulation Debugger window must be open. Must have an Input file from a previous simulation in the simulation debugger input window.

Example

```
iccap_func("SimulationDebugger","Manual Simulation")
```

Measure

Automates the Measure menu picks.

Valid Objects DUT, Setup

menu_func style command: “Measure”

Performs a measurement on all setups within named DUT or within named setup.

Example

```
iccap_func("/CGaas1/dc","Measure")
iccap_func("/CGaas1/dc/igvg_0vs","Measure")
```

Memory Recall

Automates the “Memory Recall” button on a Model Parameters page.

Valid Objects Parameter Set, Device Parameter Set

menu_func style command: “Recall Stored Values”

Restores the parameter values previously stored via Memory Store.

Example

```
iccap_func("/CGaas1/ParameterSet","Memory Recall")
iccap_func("/CGaas1/dc/DeviceParameterSet","Memory Recall")
```

See Also Memory Store (pg 941)

Memory Store

Automates the “Memory Store” button on a Model Parameters page.

Valid Objects Parameter Set, Device Parameter Set

menu_func style command: “Store Current Values”

Makes a temporary, internal, hidden copy of the current state of the parameter page.

Example

```
iccap_func("/CGaas1/ParameterSet","Memory Store")
iccap_func("/CGaas1/dc/DeviceParameterSet","Memory Store")
```

See Also Memory Recall (pg 941)

New DUT

Automates the Model window's Add... Button functionality.

Valid Objects Model

menu_func style command: none

Adds a new DUT to the named model. Prompts for the name unless one is provided as the optional third argument.

Example

```
iccap_func("/CGaas1","New DUT","Dut1")
```

New Input / Output / Transform / Plot

- New Input
- New Output
- New Transform
- New Plot

Automates the "New..." Buttons under the various setup pages.

Valid Objects Setup

menu_func style command: none

Adds a new Setup child the named Setup. Will prompt for the name unless one is provided as the optional third argument.

Example

```
iccap_func("/CGaas1/ac/s_at_f","New Input","input1")
iccap_func("/CGaas1/ac/s_at_f","New Output","output1")
iccap_func("/CGaas1/ac/s_at_f","New Transform","transform1")
iccap_func("/CGaas1/ac/s_at_f","New Plot","plot1")
```

New Macro

Automates the Macros Page New... Button functionality.

Valid Objects Model

menu_func style command: none

Adds a new macro to the named model. Prompts for the name unless one is provided as the optional third argument.

Example

```
iccap_func("/CGaas1","New Macro","Dut1")
```

New Model

Automates the IC-CAP/Main window's File > New functionality.

Valid Objects IC-CAP

menu_func style command: none

Adds a new model to the system. An optional third parameter will be the name for the model, otherwise a prompt will appear for the name of the new model.

Example

```
iccap_func("/","New Model")
iccap_func("/","New Model","MyModel")
```

New Setup

Automates the “Add...” Button under the DUTs/Setups tree.

Valid Objects DUT

menu_func style command: none

Adds a new Setup the named DUT. Will prompt for the name unless one is provided as the optional third argument.

Example

```
iccap_func("/CGaas1/dc","New Setup","Setup1")
```

Open

Automates the File > Open menu pick in the model window when replace is selected or when File > Open is chosen in the system variables window.

Valid Objects GUI Items, Model, Variables, Circuit, Parameter Set, Macro, DUT, Test Circuit, Device Parameter Set, Setup, Instrument Options, Input, Output, Transform, Plot

menu_func style command: “Read From File”

Prompts for the new name of the file to read, or uses the optional third argument if provided. This will read the file over the top of the specified object leaving the name unchanged. Destroys all previous contents of the named object.

Example

```
iccap_func("/CGaas1","Open","tmpSave.mdl")
iccap_func("/CGaas1/Variables","Open","myvars.vat")
```

See Also Open Model (pg 946), Open DUT (pg 944), Open Macro (pg 945), Open Setup (pg 947), Open Input (pg 945), Open Output (pg 945), Open Transform (pg 945), Open Plot (pg 945), ReadOnlyValues (pg 949)

Open Branch

Automates the action of opening a DUT on the DUTs/Setups tree.

Valid Objects DUT

menu_func style command: none

Opens a DUT on the DUTs/Setups tree.

Example iccap_func(“/mymodel/mydut”,”Open Branch”)

See Also Close Branch (pg 902)

Open DUT

Automates the Model window's File > Open functionality for the DUT level selection.

Valid Objects Model

menu_func style command: none

Prompts for a name of a .dut file to be read into the current model unless the optional third argument is specified as the name.

Example

```
iccap_func("/CGaas1","Open DUT","mydutfile.dut")
```

Open Error Log

Automates the IC-CAP/Status window’s File > Open Error Log functionality.

Valid Objects IC-CAP

menu_func style command: none

Opens the error log file using the file name if provided.

Example

```
iccap_func("ic-cap","Open Error Log", <optional file name>)
```

Open Hardware

Automates the IC-CAP/Main window’s Tools > Hardware Setup functionality.

Valid Objects IC-CAP

menu_func style command: “Hardware/Edit”

Opens the Hardware Setup window.

Example
```
iccap_func("ic-cap","Open Hardware")
```

Open Input / Output / Transform / Plot

- Open Input
- Open Output
- Open Transform
- Open Plot

Automates the Model window's File > Open functionality for the Input, Output, Transform, or Plot level selection.

Valid Objects Setup

menu_func style command: none

Prompts for a name of a .inp, .out, .xfm, or .plt file to be read into the current setup unless the optional third argument is specified as the name.

Example
```
iccap_func("/CGaas1/ac/s_at_f","Open Input","myInput.inp")
iccap_func("/CGaas1/ac/s_at_f","Open Output","myOutput.out")
iccap_func("/CGaas1/ac/s_at_f","Open Transform",
           "myTransform.xfm")
iccap_func("/CGaas1/ac/s_at_f","Open Plot","myPlot.plt")
```

Open Macro

Automates the Model window's File > Open functionality for the Macro level selection.

Valid Objects Model

menu_func style command: none

Prompts for a name of a .mac file to be read into the current model unless the optional third argument is specified as the name.

Example
```
iccap_func("/CGaas1","Open Macro","mydutfile.mac")
```

Open Model

Automates the IC-CAP/Main window's File > Open functionality.

Valid Objects IC-CAP

menu_func style command: none

Prompts for a name of a file from which to read models. Name of file can be specified as a third argument.

Example

```
iccap_func("/","Read Model")
iccap_func("/","Read Model","MyModel.mdl")
```

Open Output Log

Automates the IC-CAP/Status window's File > Open Output Log functionality.

Valid Objects IC-CAP

menu_func style command: none

Opens the output log file using file name if provided.

Example

```
iccap_func("ic-cap","Open Output Log", <optional file name>)
```

Open Plot Optimizer

Automates the Tools > Plot Optimizer menu pick of a model window and the Optimizer > Open Optimizer menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Opens the Plot Optimizer window.

Example

```
iccap_func("dc/fgummel/icibvsve", "OpenPlotOptimizer")
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "OpenPlotOptimizer",
            "1")
```

Open Setup

Automates the Model window's File > Open functionality for the Setup level selection.

Valid Objects Model

menu_func style command: none

Prompts for a name of a .set file to be read into the current model unless the optional third argument is specified as the name.

Example

```
iccap_func("/CGaas1/dc","Open Setup","mysetfile.set")
```

Optimize

Automates the Optimize menu picks in the Extract/Optimize folder and the Optimize > Run Optimization menu pick in the Plot Optimizer window.

Valid Objects DUT, Setup, Plot Optimizer

menu_func style command: “Extract”

Performs Transforms that are optimizers on all setups within named DUT/setup or in the Plot Optimizer window.

Example

```
iccap_func("./CGaas1/dc","Optimize")
iccap_func("./CGaas1/dc/igvg_0vs","Optimize")
iccap_func(“./PlotOptimizer”,”Optimize”)
```

Parse

Automates the "Parse..." button in the Circuit folder

Valid Objects Circuit, Test Circuit

menu_func style command: “Parse”

Checks the syntax of the Circuit in reference to the specified simulator and updates the list of parameters if they have changed names. NOTE: Parse does not assign the Parameters table values to those in the Circuit, unless they have been newly added.

Example

```
iccap_func("/CGaas1/Circuit","Parse")
```

```
iccap_func("/CGaas1/dc/TestCircuit","Parse")
```

See Also Reset (pg 953)

Print Read Buffer

Automates the functionality of the Tools > Send Receive > Display String menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIB Analyzer

menu_func style command: “Print Read String”

This function prints the ASCII string stored in the read buffer that had been read back by a call to “Read String”. The string is displayed in the IC-CAP/Status window and if visible, the Hardware Setup window.

Example

```
iccap_func("Hareware","HPIB Analyzer","Print Read Buffer")
```

Print Via Server

Automates the functionality of File > Print in the Model windows and the “Print” button on various dialogs.

Valid Objects Variables, Input, Output, Transform, Plot

menu_func style command: none (see “Send to Printer”)

Displays the Print dialog box for printing the item. Starting with IC-CAP 2004, the Print dialog box is always displayed when printing. In previous releases, File > Print did not display a dialog box except when asking for a file name if printing to a file.

For plots, Print Via Server prints a tabular listing of the data. To print the graphical plot, use Dump Via Server UI.

Example

```
iccap_func("/CGaas1/Variables","Print Via Server")
```

See Also Send To Printer (pg 965), Dump To Printer (pg 917), Dump To Plotter (pg 916), Dump Via Server (pg 918), Dump Via Server UI (pg 919)

Read from File

Automates the functionality of the File > Open menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: “Read from File”

Reads in a previously saved hardware configuration file. If this function were executed manually, a dialog box would appear asking the user for the name of the configuration file to read. This functionality is emulated in PEL by appending the desired file name followed by "ok" to the end of the command string.

Example

```
iccap_func("Hardware","Read from File","
           ../mdl/hwm_pel_test.hdw","ok")
```

ReadOnlyValues

Automates the File > Open menu pick when Read Values Only is selected in the Model Parameters folder or the DUT Parameters folder.

Valid Objects Parameter Set, Device Parameter Set

Prompts for the new name of the file to read, or uses the optional third argument if provided. This replaces parameter Values while maintaining existing Min and Max ranges if possible. If the new value is outside the existing range, Min or Max is extended to include the new Value and a warning is displayed in the Status window.

Example

```
iccap_func("./ParameterSet","ReadOnlyValues","myparms.mps")
iccap_func("/CGaas1/dc/DeviceParameterSet","ReadOnlyValues",
           "myparms.dps")
```

See Also Open (pg 943)

Read String

Automates the functionality of the Tools > Send Receive > Receive String menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Read String"

This function reads back an ASCII string from the device at the currently active address as previously set by a call to “Set Active Address”. The device should have been previously prepared to talk by sending it a string that generated something for it to say. The received string itself is not displayed; rather the number of characters read is displayed in the IC-CAP/Status window and, if visible, the Hardware Setup window. The string itself is stored in a read_buffer where a call to “Print Read Buffer” can display it later.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Read String")
```

Read String for Experts

Automates the functionality of the Tools > Send Receive > Read String for Experts menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Read String for Experts"

This function is similar to the "Read String" command except it skips the talk/listen setup of the device which should be done using the "Send Command Byte" command. The result is placed in the HPIB_READ_STRING system variable, if it has been defined.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Read String for Experts")
```

Rebuild Active List

Automates the functionality of the “Rebuild” button in the Hardware Setup window’s Instrument List field.

Valid Objects Hardware

menu_func style command: "Rebuild Active List"

Scans the bus and rebuilds the active instrument list for all DUTs and setups based on the instruments it finds there.

Example

```
iccap_func("Hardware","Rebuild Active List")
```

Recall Parameters

Automates the Tools > Recall Parameters menu pick in the Plot Optimizer window and the Recall Par button in the Extract/Optimize folder.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Resets the optimizer Parameters table values to the locally stored values.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”Recall Parameters”)
iccap_func(“./PlotOptimizer”,”Recall Parameters”)
```

See Also Store Parameters (pg 976)

Redisplay

Provided for compatibility.

Valid Objects Input, Output, Transform, Plot

menu_func style command: “Redisplay”

Refreshes the screen of the 'View Data' of the associated object.

Example

```
iccap_func("CGaas1/dc/igvg_0vs/vs","Redisplay")
```

Refresh Dataset

Automates the Model window’s Tools > Refresh Last Dataset menu pick functionality.

Valid Objects Model

Exports new data to the last exported dataset file (*.ds). If no dataset file had been successful exported, this function will have no effect.

Example

```
iccap_func("/","Refresh Dataset")
```

See Also Export Dataset (pg 922)

Release License

Automates the functionality of the Release button in the License Status window's In Use field.

Valid Objects IC-CAP

menu_func style command: none

This function releases a license for a specified licensed feature and returns it to the license pool. Specify the desired license name, followed by ok.

Valid license names are:

DC Measurements	Gummel-Poon Bipolar Model
AC Measurements	Curtice-Statz GAAS Model
LCRZ Measurements	Time Domain Measurements
HP Pulsed System Measurements	Philips MEXTRAM Model
1/f Noise Measurements	Philips MOS Model 9
Analysis	UCB MOS3 Model
IC-CAP Statistics	UCB BSIM3 Model
HP Root FET Model	UCB BSIM4 Model
HP Root MOS Model	HP EEFET3 Model
HP Root Diode Model	HP EEHEMT1 Model
VBIC BJT Model	HP EEBJT2 Model

Example

```
iccap_func("IC-CAP","Release License","DC Measurements",
           "ok")
```

Rename

Automates changing the text under the Model icon.

Valid Objects Model, Macro, DUT, Setup, Input, Output, Transform, Plot

menu_func style command: "Rename"

Prompts for the new name of the model, or uses the optional third argument if provided.

Example

```
iccap_func("/CGaas1","Rename","my_CGaas1")
```

Replace Interface File

This function is not implemented.

Replot

Automates the Options > Replot menu pick of a plot window.

Valid Objects Plot

menu_func style command: “Replot Data”

Refreshes the plot-- plot window must be open.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Replot")
```

Rescale

Automates the Options > Rescale menu pick in a plot window.

Valid Objects Plot

menu_func style command: “Rescale Graph”

Adjusts the axes to fit the data.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Rescale")
! Specify plot number for Multiplot
iccap_func("/CGaas1/dc/igvg/my_multiplot","Rescale","1")
```

Reset

Automates the “Reset” button on a Model Parameters page.

Valid Objects Parameter Set

menu_func style command: “Reset to Defaults”

Resets the parameter values to the values in the Circuit folder.

Example

```
iccap_func("/CGaas1/ParameterSet","Reset")
iccap_func("/CGaas1/dc/DeviceParameterSet","Reset")
```

Reset Global Region

Automates the Optimizer > Global Region > Reset menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Deletes all existing global trace regions on the plot and defines a new global trace region.

Example

```
iccap_func("./dc/fgummel/ibicvsve", "ResetGlobalRegion",
           "0.6", "0.8", "-8", "-3")
iccap_func("./dc/fgummel/bvsic", "ResetGlobalRegion",
            "1e-8", "1e-4", "20", "60")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "ResetGlobalRegion",
           "0.6", "0.8", "-8", "-3", "1")
```

Reset Min Max

Automates the Tools > Reset Min Max menu pick in the Plot Optimizer window and the Reset Min Max button in the Extract/Optimize folder.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Sets minimum and maximum optimizer parameter values based on the value of the coefficient defined with the AUTOSET_COEFF variable on the System Variables page. The default coefficient value is 5.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”ResetMinMax”)
iccap_func(“./PlotOptimizer”,”ResetMinMax”)
```

Reset Option Table

Automates the File > Reset Option Table menu pick in the Plot Optimizer window.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Resets all options in the Options table to the default values.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”ResetOptionsTable”)
iccap_func(“./PlotOptimizer”,”ResetOptionsTable”)
```

Reset to Saved Options

Automates the Options > Session Settings > Reset to Saved Options menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Restores the Plot Options to their saved state. For Multiplot, specify a plot number to reset the Plot Options for a specific plot. To reset the Plot Options for a Multiplot, do not specify a plot number.

Example

```
iccap_func("./dc/fgummel/bvsic", "ResettoSavedOptions")
iccap_func("./dc/fgummel/my_multiplot",
           "ResettoSavedOptions")
! Specify plot number in Multiplot to reset specific plot
iccap_func("./dc/fgummel/my_multiplot",
            "ResettoSavedOptions", "1")
```

Reset Trace Region

Automates the Optimizer > *trace* > Trace Optimizer Region > Reset menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Deletes all existing trace optimizer regions for the specified trace and defines a new trace optimizer region.

Example

```
iccap_func("./dc/fgummel/ibicvsve", "ResetTraceRegion",
            "Y Data 0", "0.6", "0.8", "-8", "-3")
iccap_func("./dc/fgummel/bvsic", "ResetTraceRegion",
           "Y Data 0", "1e-8", "1e-4", "20", "60")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "ResetTraceRegion",
            "Y Data 0", "0.6", "0.8", "-8", "-3", "1")
```

Run Self-Tests

Automates the functionality of the Hardware Setup > Instruments > Self Test menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: "Run Self-Tests"

Runs self tests on all instruments found on the bus during a rebuild of the active list or a measure. Note that to successfully perform the "Run Self-Tests" function either the "Rebuild Active List" or the "Measure" function must have been performed first.

Example

```
iccap_func("Hardware","Run Self-Tests");
```

Save All

Automates IC-CAP/Main File > Save As, but does not permit selective grouping of models into a .mdl file

Valid Objects IC-CAP

menu_func style command: “Write All Models To File”

Prompts for the name of a file and saves all loaded models to that file. Name of the file can be anticipated by the third argument.

Example

```
iccap_func("/","Save All","myfile.mdl")
```

See Also Save All No Data (pg 956), Save As (pg 957), Save As No Data (pg 957)

Save All No Data

Automates IC-CAP/Main File > Save As with the "Save without measured/simulated data" option, but does not permit selective grouping of models into a .mdl file

Valid Objects IC-CAP

menu_func style command: none

Prompts for the name of a file and saves all loaded models to that file without any measured or simulated data. Name of the file can be anticipated by the third argument.

Example `iccap_func("/","Save All No Data")`

See Also Save As (pg 957), Save All No Data (pg 956)

Save As

Automates the Model window's File > Save As functionality for the Model level selection.

Valid Objects GUI Items, Model, Variables, Circuit, ParameterSet, Macro, DUT, TestCircuit, DeviceParameterSet, Setup, InstrumentOptions, Input, Output, Transform, Plot

menu_func style command: “Write To File”

Prompts for a name of a .mdl file to be written unless the optional third argument is specified as the file name.

If the third parameter is "", then the function will write the file out to the default name. The default name is the name of the file that it was read in from, or the name of the last file to which it was written.

Example `iccap_func("/CGaas1","Save As","tmpFile.mdl")`

See Also Save All (pg 956), Save All No Data (pg 956), Save As No Data (pg 957)

Save As No Data

Automates the Model window's File > Save As functionality for the Model level selection choosing the "Save Without Measured/Simulated Data" option.

Valid Objects Model, Variables, Circuit, Parameter Set, Macro, DUT Test Circuit, Device Parameter Set, Setup, Instrument Options, Input, Output, Transform, Plot

menu_func style command: none

Prompts for a name of a .mdl file to be written unless the optional third argument is specified as the file name.

If the third parameter is "", then the function will write the file out to the default name. The default name is the name of the file that it was read in from, or the name of the last file to which it was written.

Example
```
iccap_func("/CGaas1","Save As No Data","smallFile.mdl")
```

See Also Save All (pg 956), Save All No Data (pg 956), Save As (pg 957)

Save Extracted Deck

Automates the Model window's File > Export Data > Extracted Deck functionality.

Valid Objects Model

menu_func style command: “Save Extracted Deck”

Merges the current Parameters table into the current circuit and writes the results to a file. An optional third argument can specify the name of the file or the iccap_func will prompt for a name.

Example
```
iccap_func("/CGaas1","Save Extracted Deck","my_deck")
```

Save Image

Automates the File > Save Image menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Saves an image of the named plot in .xwd format using the specified file name.

Example
```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Save Image",
           "nmos2_idvsvg.xwd")
```

Save Input / Command / Output File

- Save Input File
- Save Command File
- Save Output File

Automates the IC-CAP/Simulation Debugger File > Save Input File, File > Save Output File, or File > Save Command File functionality.

Valid Objects Simulation Debugger

menu_func style commands were the same

Saves a copy of the last input, output or command file sent to the simulator with the Simulation Debugger open. A simulation must have previously been run with the Simulation Debugger open. An optional third command can be specified to name the file.

Example

```
iccap_func("Simulation Debugger","Save Input File")
iccap_func("Simulation Debugger","Save Command File")
iccap_func("Simulation Debugger","Save Output File",
           "myOutFile)
```

Scale Plot / Scale Plot Preview

- Scale Plot
- Scale Plot Preview

Automates the Options > Manual rescale... menu pick in a plot window (except for Polar Graph and Smith Chart–see "Scale RI Plot/Scale RI Plot Preview" on page 960).

Valid Objects Plot

menu_func style command: none

Prompts appear for you to enter required values for the parameters that describe the plot's scaling values. The prompts appear in the following order for the X axis first, then the Y axis, and finally the Y2 axis:

1. minimum scale value
2. maximum scale value
3. number of major divisions
4. number of minor divisions

Entering *AUTOMATIC* for an axis' minimum value (the first prompt), sets that axis to autoscaled and no further prompts will appear for that axis.

Scale Plot Preview functions the same way as Scale Plot, but the scaling will be lost on the next Replot command.

You can anticipate the prompts and include the scale values for the parameters in the required order. The following example sets the plot's scale to the values listed in the table:

Example

```
iccap_func("Plot","Scale Plot","0","100","10","5",
           "-10","10","5","1","AUTOMATIC")
! Specify plot number for Multiplot
iccap_func("Multiplot","Scale Plot","0","100","10","5",
           "-10","10","5","1","AUTOMATIC","1")
```

Axis	Minimum	Maximum	Major Divisions	Minor Divisions
X	0	100	10	5
Y	-10	10	5	1
Y2	Autoscaled			

See Also Scale RI Plot/Scale RI Plot Preview (pg 960)

Scale RI Plot / Scale RI Plot Preview

- Scale RI Plot
- Scale RI Plot Preview

Automates the Options > Manual rescale... menu pick in a real-imaginary plot window (RI Graph, Polar Graph, and Smith Chart).

NOTE You can scale RI Graph plots using *either* Scale Plot or Scale RI Plot. All other plot types can only be scaled using one scale type—not both. For Polar Graph and Smith Chart plot types, you can only use Scale RI Plot. For all other plot types, you can only use Scale Plot.

Valid Objects Plot

menu_func style command: none

Prompts appear for you to enter required values for the parameters that describe the plot's scaling values. The prompts appear in the following order:

1 Format for Center Point (RI, Z or MP)
   - RI - Real/Imaginary
   - Z - Normalized Real/Imaginary (Smith Chart format)
   - MP - Magnitude/Phase
2 Center Point Val1 (Real, Normalized Real, or Magnitude)
3 Center Point Val2 (Imaginary, Normalized Imaginary, or Phase)
4 Radius Magnitude
5 Number of divisions on Real Axis
6 Number of subdivisions per division on Real Axis
7 Number of divisions on Imaginary Axis
8 Number of subdivisions per division on Imaginary Axis

Scale RI Plot Preview functions the same way as Scale RI Plot, but the scaling will be lost on the next Replot command.

You can anticipate the prompts and include the scale values for the parameters in the required order.

Example

```
iccap_func("polar_plot","Scale RI Plot","MP","1","3.14","1",
           "5","4","5","4")
! Specify plot number for Multiplot
iccap_func("polar_plot","Scale RI Plot","MP","1","3.14","1",
           "5","4","5","4","1")
```

See Also Scale Plot/Scale Plot Preview (pg 959)

Screen Debug On

Automates functionality of IC-CAP/Main Tools > Options > Screen Debug.

Valid Objects IC-CAP

menu_func style command: "Utilities/Screen Debug On"

Logs all debug information to the IC-CAP/Status window.

NOTE Screen Debug On automatically turns File Debug Off.

Example
```
iccap_func("ic-cap","Screen Debug On")
```

See Also Debug Off (pg 923), Screen Debug Off (pg 923)

Search for Instruments

Automates the functionality of the Instruments > Find menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Search for Instruments"

Using the currently active interface, this function sends a serial poll to all possible addresses other then that of the interface card itself. The results are displayed in the IC-CAP/Status window and if visible, the Hardware Setup window.

Example
```
iccap_func("Hardware/HPIBAnalyzer","Search for Instruments")
```

Select Error Region

Automates the Options > Error > Select Error Region menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Example
```
iccap_func("./dc/fgummel/bvsic", "SelectErrorRegion")
iccap_func("./dc/fgummel/bvsic", "SelectErrorRegion",
           "x1", "x2", "y1", "y2")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "SelectErrorRegion",
           "1")
iccap_func("./dc/fgummel/my_multiplot", "SelectErrorRegion",
           "x1", "x2", "y1", "y2", "1")
```

See Also Select Whole Plot (pg 963), Show Absolute Error (pg 973), Show Relative Error (pg 974)

Select Plot

Automates the Plots > Select Plot menu item in a Multiplot window

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "SelectPlot")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "SelectPlot", "1")
```

See Also Unselect All (pg 979)

Select Whole Plot

Automates the Options > Error > Select Whole Plot menu item in a plot window

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "SelectWholePlot")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "SelectWholePlot",
           "1")
```

See Also Select Error Region (pg 962), Show Absolute Error (pg 973), Show Relative Error (pg 974)

Send Command Byte

Automates the functionality of the Tools > Send Receive > Send Byte menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Send Command byte"

This command sends one low_level command byte, specified as a decimal integer, to the currently active address. The following list summarizes the GPIB low_level byte commands in common use.

Mnemonic	Definition	Byte
ATN	Attention	
DCL	Device Clear	20
EOI	End or Identify	
EOL	End of Line	
GET	Group Execute Trigger	8
GTL	Go To Local	1
IFC	Interface Clear	
LAD	Listen Address	32 + address
LLO	Local Lockout	17
MLA	My Listen Address	
MTA	My Talk Address	
OSA	Other Secondary Address	
PPC	Parallel Poll Configure	5
PPD	Parallel Poll Disable	
PPU	Parallel Poll Unconfigure	21
REN	Remote Enable	
SDC	Selected Device Clear	4
SPD	Serial Poll Disable	25
SPE	Serial Poll Enable	24
SRQ	Service Request	
TAD	Talk Address	64 + address
UNL	Unlisten	63
UNT	Untalk	95

Example

```
iccap_func("Hardware/HPIBAnalyzer","Send Command Byte","63",
           "ok")
```

Send, Receive, and Print

Automates the functionality of the Tools > Send Receive > Send Receive Display menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Send, Receive, and Print"

This command sends a string the currently active address, reads back and displays the response. If this function were executed manually, a dialog box would appear asking for the string to be sent. This functionality is emulated in PEL by appending the desired string followed by "ok" to the command line string.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Send, Receive, and
           Print","*IDN?\n","ok")
```

Send String

Automates the functionality of the Tools > Send Receive > Send String menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Send String"

This function sends an ASCII to the device at the currently active address. If this function were executed manually, a dialog box would appear asking for the string to be sent. This functionality is emulated in PEL by appending the desired string followed by “ok” to the command line string. The result is displayed in the IC-CAP/Status window and, if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Send String","*IDN?\n")
```

Send To Printer

Provided to be compatible with Version 4.5 style of printing

Valid Objects Variables, Input, Output, Transform, Plot

menu_func style command: “Send To Printer”

Prompts for the name of the command through which to pipe the required file. May be anticipated by a third argument.

Example

```
iccap_func("/CGaas1/Variables","Send To Printer",
           "lp -dmyprinter")
iccap_func("/CGaas1/Variables","Send To Printer","cat")
```

See Also Print Via Server (pg 948),Dump To Printer (pg 917), Dump To Plotter (pg 916), Dump Via Server (pg 918)

Serial Poll

Automates the functionality of the Tools > Serial Poll menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Serial Poll"

This function sends a serial poll command to the device at the currently active address. The result is displayed in the IC-CAP/Status window and if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Serial Poll")
```

Set Active Address

Automates the functionality of the Tools > Address > Set menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Set Active Address"

Sets the address to which the GPIB Analyzer commands will be sent. If this menu pick were done manually, a dialog box would appear asking for the desired address. This functionality is emulated in PEL by appending the desired address followed by “ok” to the end of the command string.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Set Active Address",
           "8","ok")
```

Set Algorithm

Automates the Algorithm drop down menu pick in an Extract/Optimize folder or in a Plot Optimizer window.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Sets the optimization algorithm to one of the following choices:

Algorithm Full Name	PEL Code
Levenberg-Marquardt	L
Random	R
Hybrid (Random/LM)	H
Sensitivity Analysis	S
Random (Gucker)	A
Gradient	B
Random Minimax	U
Gradient Minimax	E
Quasi-Newton	G
Least P^{th}	I
Minimax	N
Hybrid (Random/Quasi-Newton)	P
Genetic	Q

Example

```
iccap_func("./PlotOptimizer", "SetAlgorithm", "Minimax")
iccap_func("dc/fgummel/optim1", "SetAlgorithm", "B")
```

Set Error

Automates the Error drop down menu pick in an Extract/Optimize folder or in a Plot Optimizer window.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Sets the optimization error to either Relative or Absolute.

Example

```
iccap_func("./PlotOptimizer", "SetError", "Relative")
iccap_func("dc/fgummel/optim1", "SetError", "Absolute")
```

Set GUI Callbacks

Allows setting a callback on a GUI item.

Valid Objects GUI Item

menu_func style command: none

This action requires three other arguments. The first is the code for the callback. The second and third extra argument are the two parameters to the callbacks associated iccap_func().

Example

```
iccap_func("./someItem","Set GUI Callback", "AC", "aMacro",
           "Execute)
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Options (pg 968)

Set GUI Options

Automates changing options for any Item on a GUI Page.

Valid Objects GUI Item

menu_func style command: none

You can enter as many additional arguments as desired. The last argument must be "" (a null string) to signify completion. Each argument is of the form <code>=<val>. Code is the associated code for the option as found by choosing *Show Codes* on the properties dialog.

The <val> can be one of four forms:

- A literal

  <val> may be a string or a number

- A Variable Changed

  If the first character after the equal sign is a %, the value is taken to track a variable by the given name.

- An Enumerated type code

  Many options have enumerated types such as list selection mode. Each of these possible values has an associated code that can be viewed on the properties dialog.

- Multiple Enumerated types

  Some options (e.g., sizing options) allow multiple enumerated types to be set (fixed width and fixed height). These are indicated by specifying <code>|<code>.

Example

```
iccap_func("./someItem","Set GUI Options", "OR=HO",
           "CA="title","")
iccap_func("./some.other.item","Set GUI Options",
            "TO=FW|FH","")
```

See Also Add GUI (pg 894), Close GUI (pg 903), Close Single GUI (pg 904), Destroy GUI (pg 910), Destroy Single GUI (pg 911), Display Modal GUI (pg 914), Display Modeless GUI (pg 914), Display Single Modal GUI (pg 915), Display Single Modeless GUI (pg 916), Set GUI Callbacks (pg 968)

Set Instrument Option Value

Valid Objects Input, Output

menu_func style command: none

Allows setting the option fields in an instrument option table.

Example

```
iccap_func("c/c/x","SetInstrumentOptionValue","Delay Time",
           "foo")
```

Set Speed

This function is not implemented in IC-CAP Version 5.0

Set Table Field Value

Automates deleting variables and setting Input, Output, Plot, and all Transform fields.

Valid Objects

Input, Output, Plot, Transform, PlotOptimizer, PlotOptions, Variables

menu_func style command: none

To set a Transform function, use the field name “Function”. To set the text for the body of a PEL program, use the field name “Program”. To set fields in two dimensional tables, such as the optimizer's input and parameter tables, use [ ] to indicate which row you want to set. Identify the row using either the row’s index number or the name in the first field of the row. For example:

```
Name     Value    Min    Max
BF        100     50     150
IS        100a    50a    120a
```

To access the Min of BF use:

"Min[0]" (0 is the index number for the first row.)
or
"Min[BF]" (BF is the name in the first field of the row and it must be unique to correctly identify the row.)

If you set the start, stop, or number of points for an input, follow with a “Redisplay” statement to recalculate its size. Only a single “Redisplay” statement is needed after setting multiple input fields.

Action name may be shortened to “STFV” for brevity.

See the following examples:

Example

```
iccap_func("dc/fgummel/ic","SetTableFieldValue","Mode","V")
iccap_func("myplot","SetTableFieldValue","Header","This is
           the header")
iccap_func("dc/fgummel/myxform","SetTableFieldValue",
           "Function","Program")
iccap_func("dc/fgummel/myxform","SetTableFieldValue",
           "Program","!autogenerated
           print 'This is an autogenerated PEL'")
iccap_func("dc/fgummel/optim1","SetTableFieldValue",
           "Target[1]","ib.m")
iccap_func("dc/fgummel/optim1","SetTableFieldValue",
           "Simulated[1]","ib.s")
```

```
iccap_func("dc/fgummel/optim1","STFV","Name[2]","BF")
iccap_func("vd","SetTableFieldValue","# of Points","100")
iccap_func("vd","Redisplay")
iccap_func("./PlotOptimizer", "STFV", "Print Parameters", "N")
iccap_func("./PlotOptimizer", "STFV", "Name[0]", "BF")
iccap_func("./ParameterSet", "STFV", "Min[BF]", "100a")
iccap_func("./ParameterSet", "STFV", "Max[BF]", "150")
iccap_func("./ParameterSet", "STFV", "Param Value[BF]", "100")
! Deleting varibles: First argument can be Model, DUT,
! Setup, or the slash (/) to specify top-level IC-CAP object.
iccap_func(".","STFV","Name[aaa]","") ! Changes the value
! of the Name cell corresponding with "aaa" to "".
```

See Also Redisplay (pg 951)

Set Target Vs Simulated

Automates the Optimizer > *trace* > Set as Target vs. menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Configures the specified trace as Target versus a specified Simulated trace.

Example

```
iccap_func("./dc/rgummel/ibievsvc", "SetTargetVsSimulated",
           "Y Data 0", "Y Data 1")
! Specify plot number for Multiplot
iccap_func("./dc/rgummel/my_multiplot", "SetTargetVsSimulated",
           "Y Data 0", "Y Data 1", "1")
```

See Also Set Trace As Both (pg 972)

Set Timeout

Automates the functionality of the Tools > Settings > Timeout menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Set Timeout"

Sets the timeout of the device at the currently active address as previously set by a call to “Set Active Address”. If this function were executed manually, a dialog box would appear asking for

the desired timeout, in seconds. This functionality is emulated in PEL by appending the desired timeout followed by “ok” to the end of the command string.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Set Timeout","10","ok")
```

Set Trace As Both

Automates the Optimizer > *trace* > Set as Both Target and Simulated menu pick in a plot window

Valid Objects Plot

menu_func style command: none

Configures the selected trace with its measured data set as Target and its simulated data set as Simulated.

Example

```
iccap_func("dc/fgummel/icibvsve", "SetTraceAsBoth", "Y Data 1")
! Specify plot number for Multiplot
iccap_func("dc/fgummel/my_multiplot", "SetTraceAsBoth",
           "Y Data 1", "1")
```

See Also Set Target Vs Simulated (pg 971)

Set User Region

Defines a user region.

Valid Objects Plot

menu_func style command: none

User boxes are colored squares that you can define using the following syntax:

```
iccap_func("<plotName>", "SetUserRegion", "<RegionName>",
"x1" ,"x2", "y1", "y2", "<color>", "<ReferenceAxis>")
```

Where:

<RegionName> is a unique name that identifies the region

x1, x2, y1, y2 are the string coordinates of the region

<color> is a number between 0 and 127

<ReferenceAxis> is either "Y" or "Y2" and is used to apply the coordinates in one axis or the other.

Example

```
x=lookup_obj_attribute("ibicvsve","UserSelectedRegion")
iccap_func("ibicvsve","SetUserRegion","LeftRegion",x[0],x[1],
            x[2],x[3],5,"Y2")
```

See Also Delete All User Regions (pg 910), Delete User Region (pg 910)

Set Variable Table Value

Automates adding a new variable to a Variable table.

Valid Objects IC-CAP, Model, DUT, Setup

menu_func style command: none

Uses two anticipated arguments to name the variable and value to be set. If the named variable does not exist on the object named, the system searches upwards through the hierarchy to find it.

Examples

```
iccap_func("/npn","SetVariableTableValue","SIMULATOR",
           "spice3")
```

See Also Set Table Field Value (pg 970), Create Variable Table Variable (pg 906)

Show Absolute Error

Automates the Options > Error > Show Absolute Error menu item in a plot window

Valid Objects Plot

menu_func style command: none

Displays the MAX and RMS absolute errors in the footer area and turns off relative error or footer text if displayed.

Example

```
iccap_func("./dc/fgummel/bvsic", "ShowAbsoluteError")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "ShowAbsoluteError",
           "1")
```

See Also Show Relative Error (pg 974), Select Whole Plot (pg 963), Select Error Region (pg 962)

Show Relative Error

Automates the Options > Error > Show Relative Error menu item in a plot window

Valid Objects Plot

menu_func style command: none

Displays the MAX and RMS relative errors in the footer area and turns off absolute error or footer text if displayed.

Example

```
iccap_func("./dc/fgummel/bvsic", "ShowRelativeError")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "ShowRelativeError",
           "1")
```

See Also Show Absolute Error (pg 973), Select Whole Plot (pg 963), Select Error Region (pg 962)

Simulate

Automates the Simulate menu picks.

Valid Objects DUT, Setup

menu_func style command: “Extract”

Performs Simulation on all setups within named DUT or within named setup.

Example

```
iccap_func("/CGaas1/dc","Simulate")
iccap_func("/CGaas1/dc/igvg_0vs","Simulate")
```

Simulate All

Automates the Simulate > Simulate All menu pick in the Plot Optimizer window.

Valid Objects Plot Optimizer

menu_func style command: none

Simulates all enabled traces.

Example

```
iccap_func(“./PlotOptimizer”,”SimulateAll”)
```

Simulate Plot Inputs

Automates the Simulate > *plot name* menu pick in the Plot Optimizer window.

Valid Objects: Plot Optimizer

menu_func style command: none

Simulates all enabled traces in the specified plot.

Example:
```
iccap_func(“./PlotOptimizer/optim1”,”SimulatePlotInputs”)
```

Simulation Debugger

Automates the IC-CAP/Main window’s Tools > Simulation Debugger functionality.

Valid Objects: IC-CAP

menu_func style command was “Utilities/Open Simulation Debugger”

Example:
```
iccap_func("ic-cap","Simulation Debugger")
```

Status Window

Automates the IC-CAP/Main window’s Windows > Status Window functionality.

Valid Objects: IC-CAP

menu_func style command: none

Raises the Status window to the top of the screen

Example:
```
iccap_func("ic-cap","Status Window")
```

Stop Simulator

Automates the IC-CAP/Main and Model window’s Tools > Stop Simulator functionality.

Valid Objects: IC-CAP, Model

menu_func style command: none

If a simulator is configured for CAN_PIPE mode, this action will stop any currently running simulator. If the current simulator is not CAN_PIPE, or if no simulator is currently running, this action will do nothing.

Example

```
iccap_func("/","Stop Simulator")
```

Store Parameters

Automates the Tools > Store Parameters menu pick in the Plot Optimizer window and the Store Par button in the Extract/Optimize folder.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Locally stores the current parameter values to the Stored column on the optimizer Parameters table. When the file is saved, these values are stored as part of the optimizer settings.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”Store Parameters”)
iccap_func(“./PlotOptimizer”,”Store Parameters”)
```

See Also Recall Parameters (pg 951)

Talk Active Address

Automates the functionality of the Tools > Address > Talk menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: "Talk Active Address"

This function sends a TALK command to the device at the currently active address. The result is displayed in the IC-CAP/Status window and if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Talk Active Address")
```

Text Annotation

Automates the Options > Session Settings > Text Annotation menu pick in a plot window.

Valid Objects Plot

menu_func style command: none

Toggles Text Annotation on and off for the specified plot.

Example

```
iccap_func("./dc/fgummel/bvsic", "TextAnnotation")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot","TextAnnotation","1")
```

See Also Text Annotation Off (pg 977), Text Annotation On (pg 977)

Text Annotation Off

Turns off text annotation for the specified plot.

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "TextAnnotationOff")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "TextAnnotationOff",
           "1")
```

See Also Text Annotation (pg 976), Text Annotation On (pg 977)

Text Annotation On

Turns on text annotation for the specified plot.

Valid Objects Plot

menu_func style command: none

Example

```
iccap_func("./dc/fgummel/bvsic", "TextAnnotationOn")
! Specify plot number for Multiplot
iccap_func("./dc/fgummel/my_multiplot", "TextAnnotationOn",
           "1")
```

See Also Text Annotation (pg 976), Text Annotation Off (pg 977)

Toggle Zoom

Automates the Plots > Zoom Plot menu pick in a Multiplot window.

Valid Objects Plot

menu_func style command: none

In the Multiplot window, displays the selected plot in zoom format.

Example

```
iccap_func("./dc/fgummel/my_multiplot","ToggleZoom","1")
```

See Also Zoom Plot (pg 981), Undo Zoom (pg 979), Full Page Plot (pg 925)

Tune Fast

Automates the Tune Fast button in the Extract/Optimize folder and in the Plot Optimizer window.

Valid Objects Setup, Transform, Plot Optimizer

menu_func style command: none

Displays set of sliders enabling you to constantly tune set of optimization parameters during an optimization. The object name must include the optimization transform name.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs/optim1”,”Tune Fast”)
iccap_func(“./PlotOptimizer/optim1”,”Tune Fast”)
```

Tune Slow

Automates the Tune Slow button in the Extract/Optimize folder and in the Plot Optimizer window.

Valid Objects Setup, Transform, Plot Optimizer

menu_func style command: none

Displays set of sliders enabling you to tune set of optimization parameters during an optimization. The object name must include the optimization transform name.

Example

```
iccap_func(“/CGaas1/dc/igvg_0vs/optim1”,”Tune Slow”)
iccap_func(“./PlotOptimizer/optim1”,”Tune Slow”)
```

Undo Optim

Automates the Undo Optim button in the Extract/Optimize folder and in the Plot Optimizer window.

Valid Objects Transform, Plot Optimizer

menu_func style command: none

Resets the parameter values in the optimizer Parameters table to values prior to the optimizations and runs a simulation.

Example

```
iccap_func(“./CGaas1/dc/igvg_0vs”,”Undo Optim”)
iccap_func(“./PlotOptimizer”,”Undo Optim”)
```

Undo Zoom

Automates the Plots > Undo Zoom menu pick in a Multiplot window.

Valid Objects Plot

menu_func style command: none

Resets the Multiplot window to its default format.

Example

```
iccap_func("./dc/fgummel/my_multiplot","UndoZoom","1")
```

See Also Full Page Plot (pg 925), Toggle Zoom (pg 977), Zoom Plot (pg 981)

Unselect All

Automates the Plots > Unselect All menu pick in a Multiplot window

Valid Objects Plot

menu_func style command: none

In the Multiplot window, unselects the currently selected plot.

Example

```
iccap_func("./dc/fgummel/my_multiplot","UnselectAll")
```

See Also Select Plot (pg 963)

Update Annotation

Automates the Options > Update Annotation menu pick in a plot window.

Valid Objects Plot

menu_func style command: “Replot Data”

If an annotation file exists for the plot, this will update the display to make it current with the contents of the annotation.

Example

```
iccap_func("/CGaas1/dc/igvg_0vs/vs/ig_vs_vg","Update
           Annotation")
```

View

Automates the View button on the Setup Pages.

Valid Objects Input, Output, Transform, Plot

menu_func style command: “Display Data”

Opens a window containing the data contained in the named item.

Example

```
iccap_func("CGaas1/dc/igvg_0vs/vs","View")
```

Who Are You

Automates the functionality of the Tools > Address > Who Are You? menu pick in the Hardware Setup window.

Valid Objects Hardware/HPIBAnalyzer

menu_func style command: none

This function tries to determine the identity of the device at the currently active address as previously set by a call to “Set Active Address”. The result is displayed in the IC-CAP/Status window and if visible, the Hardware Setup window.

Example

```
iccap_func("Hardware/HPIBAnalyzer","Who Are You")
```

Write to File

Automates the functionality of the File > Save menu pick in the Hardware Setup window.

Valid Objects Hardware

menu_func style command: “Save to File”

Saves the current hardware configuration to a file. If this function were executed manually, a dialog box would appear asking the user for the name of the file to which the current

configuration was to be saved. This functionality is emulated in PEL by appending the desired file name followed by "ok" to the end of the command string.

Example

```
iccap_func("Hardware","Save to File","
           ../mdl/hwm_pel_test.hdw","ok")
```

Zoom Plot

Automates the Plots > Zoom Plot menu pick in a Multiplot window.

Valid Objects Plot

menu_func style command: none

In the Multiplot window, displays the selected plot in zoom format.

Example

```
iccap_func("./dc/fgummel/my_multiplot","ZoomPlot","1")
```

See Also Undo Zoom (pg 979), Toggle Zoom (pg 977), Full Page Plot (pg 925)

G
54120 Demo

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The 54120.demo.mdl file is included to provide you with examples of using the 54120 series digitizing oscilloscopes. The model file shows how to construct a Model, DUT, and Setup for time-domain measurement and simulation. The model file actually contains three different models, one for each of the following modes of operating a scope:

- TDR
- Standard Time-Domain
- Standard Time-Domain with IC-CAP controlled pulse generator

The DUTs modeled in these three examples are fairly degenerate, being just lengths of cables, modeled as transmission lines. No extractions have been set up, but both Setups can be simulated and measured, and the simulated waveforms appear in plots with the measured waveforms.

NOTE The 'Standard Time-Domain' and 'Standard Time-Domain with IC-CAP controlled pulse generator' are also available with the HP 54510 oscilloscope.

TDR Example

After loading the model file (54120.demo.mdl), open the mdltdr model for this example.

In this example, the setup tdr_setup makes measurements using the scope's internal capabilities for sourcing a TDR pulse train. The acquisition of reflected and transmitted waveforms is demonstrated, and the waveforms are plotted.

Measurement / Instrument Setup

The instrument setup is an HP 54123T oscilloscope with a 1 meter 50-ohm cable, part no. 8120-4948, attached from the channel 1 port to the channel 4 port. (Be sure to issue the Rebuild command so the oscilloscope will be recognized by IC-CAP.)

Simulation

The circuit for this model contains a transmission line to simulate the cable, and it contains a 50-ohm resistor to simulate the loading offered by the channel 4 input.

The 50 ohms present as a channel 1 source impedance are automatically accounted for in the tdr_step input. See the Table 109 for details.

Setup specifics

Edit the tdr_setup setup (mdltdr) as described in the following input and output tables.

Table 109 Inputs

Input Name	Value / Description
time	This input is necessary to specify the time window for which the measured and simulated data will be acquired. It uses the Mode T. Naming it time is not necessary.
tdr_step	This input describes the pulse stimulus. Note the following comments on some of the important fields: Mode: must be V + Node and - Node: points at which the simulated pulse is applied Unit: scope channel from which TDR pulse is sourced. The scope can only source from its left-most port, generally designated as CH1. Type: must be TDR Pulsed Value: Note: 400m is used here. The manual states "a pulsed value of 200mv" is what the scope will deliver. This is true when the scope delivers its pulse across a 50-ohm load. The open-circuit value is actually 400mV, and that is what is required here for agreement between measured and simulated waveforms. This value will affect simulated data only—the scope provides no flexibility in its pulse magnitude. Delay Time, Rise Time, Fall Time, Pulse Width, Resistance: These are all selected to cause the simulator to use a signal specification roughly compatible with the 54120-family TDR pulse specification. Changing these values will affect simulated data only. Period: Values from 2usec to 65535usec can be chosen, which will affect both measured and simulated data. For simulation, the limits are actually much wider

Table 110 Outputs

Output Name	Value / Description
tdtout	This output will collect a waveform on the 4th input port of the scope. Note the use of CH4, and the Mode V. This is transmission data, in that it is what is transmitted through the cable, from CH1.
tdrout	This output will collect a waveform on the 1st input port of the scope. Note the use of CH1 to specify this. During simulation, the waveform is captured across the + and - Nodes shown. This is reflection data, because it is the waveform reflected from the cable and CH4 back to CH1, where the stimulus originates.

Standard Time-Domain Example

After loading the 54120.demo.mdl model file, open the mdl8112 model for this example. This example demonstrates using an external signal generator with a scope. IC-CAP will not directly control the signal generator, so you must control it from its front panel. An HP 8112A 50 MHz pulse generator was used while developing this model.

In this example, the setup td_meas makes measurements assuming that an external signal generator (an HP 8112) is attached to the DUT and the scope. This arrangement provides much greater flexibility in the characteristics of the stimulus delivered to the DUT (the scope's pulse generator has limited flexibility, by comparison, with an instrument such as the HP 8112).

In this setup, waveforms are acquired on two scope inputs. Also, IC-CAP exercises the scope's ability to compute peak-to-peak and rms voltages. These computed voltages appear on the same plot as the waveforms, for visual comparison.

Measurement / Instrument Setup

The instrument setup includes an HP 54123T oscilloscope with an HP 8112A generator. You will need several BNC/APC-3.5 adapters.

Note: If the attenuators suggested on the scope inputs are not used, reduce the 8112 output signal below 320mV and adjust the Pulsed Value (in the input mdl8112/dut_8112/td_meas/ext_pulse) accordingly. (See Table 111 for details.) A suitable attenuator for 3.5mm connectors is part no. 33340C.

- Triggering

  A 1 meter, 50-ohm cable is run from the Trigger output of the 8112, onto a 20dB attenuator on the Trigger input of the scope.

- Signals

A 61cm 50-ohm BNC cable, 8120-1839, is run from the 8112's signal output to a BNC T-connector. The T feeds scope channel 1 through a 20dB attenuator. The T also feeds a1 meter, 50-ohm cable, 8120-4948, which feeds scope channel 4 through another 20dB attenuator. Add BNC/APC-3.5 adapters as needed.

By pressing the scope's LOCAL key and then its AUTOSCALE key, you can see if it is receiving trigger and input signals properly. (Two waveforms should appear on the scope's display.)

Be sure to issue the Rebuild command so the oscilloscope will be recognized by IC-CAP.

Simulation

The circuit for this model contains a transmission line to simulate the cable run from scope channel 1 to scope channel 4; this helps model the delay that will be apparent in the plotted waveforms. The circuit also contains 50-ohm resistors to simulate the loading offered by the channel 1 input and the channel 4 input. (These resistors would probably be more appropriately represented in a test circuit for the DUT dut_8112.)

The source impedance of the HP 8112 generator is automatically accounted for in the ext_pulse input, which exists in the setup td_meas. (See Table 111 for details.)

Setup specifics

Edit the td_meas setup (mdl8112) as described in the following input and output tables.

Table 111 Inputs

Input Name	Value / Description
time	This Input is necessary to specify the time window for which the measured and simulated data will be acquired. It uses the Mode T. Naming it time is not necessary. The start and stop times are selected so that several complete waveforms will be plotted.

Table 111 Inputs

Input Name	Value / Description
ext_pulse	This Input describes the pulse stimulus, for Simulation purposes. For measurement, you should attempt to key in the same values on the front panel of the pulse generator being used. Note the following comments on some of the important fields: Mode: must be V + Node and - Node: points across which a simulated pulse is applied Unit: The special case GROUND is employed here to instruct IC-CAP to suppress the scope's own step generator. This makes it possible for the external pulse generator to be employed during measurement. By selecting Unit = GROUND, this ext_pulse input is effectively not used during the Measure menu selection. However, it is included for Simulate. Type: Must be TDR Pulsed Value: 3.3 was the value used to generate the measured data seen in the plot for this Setup. Unless you have 20dB attenuators on the scope inputs (a suitable attenuator for 3.5mm connectors is part no. 33340C), this value should be adjusted below 320mv, and the pulse generator should be adjusted similarly. Rise Time, Fall Time, Pulse Width: On the pulse generator, attempt to set these as shown in the IC-CAP Setup. Delay Time, Resistance: These were determined empirically using the HP 8112 to develop this demonstration. You may find different values give better agreement between the measured and simulated waveforms. Period: Enter the same value in the IC-CAP Setup and on the generator's front panel. 200n was used for the waveforms shown.

Table 112 Outputs

Output Name	Value / Description
wave1	This output will collect a waveform on the 1st input port of the scope. Note the use of CH1 to specify this. The Mode should be V. The simulated waveform is captured across the + and - Nodes shown.
wave4	This output will collect a waveform on the 4th input port of the scope. Note the use of CH4, and the Mode V. The simulated waveform is captured across the + and - Nodes shown. With the suggested cabling arrangement, the data of this output is slightly delayed, relative to the wave1 output.
vpp1	This output is only available for measurement (note the type M) because the oscilloscope computes it using special firmware algorithms. The Mode T is used to request these special Time-domain computations from the scope. By pressing the middle mouse button on the field Pulse Param, you can obtain help (in the Status panel) regarding the choices available from the scope. In this case, the peak-to-peak voltage associated with the measured part of wave1 will be obtained.
vpp4	This output is like vpp1, but obtains measured peak-to-peak voltage for CH4 and wave4.
vrms4	This output obtains measured RMS voltage for CH4 and wave4.

Controlled Pulse Generator Example

This example demonstrates a standard time-domain mode where the pulse generator is controlled by IC-CAP. It uses an external signal generator with a scope. IC-CAP directly controls the HP 8130A pulse generator. After loading the 54120.demo.mdl model file, open the mdl8130 model for this example.

In this example, the setup td_meas controls an external signal generator (an HP 8130) that is attached to the DUT and the scope. In this setup, a waveform is acquired on one scope input. Also, IC-CAP exercises the scope's ability to compute period, +width, -width, risetime, falltime, and peak-to-peak voltage.

Measurement / Instrument Setup

The hardware arrangement includes an HP 54123T oscilloscope with an HP 8130A generator. You will need several BNC/APC-3.5 adapters.

NOTE If the attenuators suggested on the scope inputs are not used, adjust the Pulsed Value (in the input mdl8130/dut_8130/td_meas/ext_pulse) so that it is below 320mV. (See Table 113 on page 992 for details.) A suitable attenuator for 3.5mm connectors is part no. 33340C.

- Triggering

  A 1 meter, 50-ohm cable is run from the Trigger output of the 8130, onto a 20dB attenuator on the Trigger input of the scope.

- Signals

  A 61cm 50-ohm BNC cable, 8120-1839, is run from the 8130's signal output to a BNC/APC-3.5 adapter connected to scope channel 1 through a 20dB attenuator. Additionally, the signal can be fed to scope channel 1 through the use of a BNC T-connector as described in the 8112 case.

Be sure to issue the Rebuild command so the oscilloscope will be recognized by IC-CAP.

Simulation

The circuit for this model contains a transmission line to simulate the cable run from scope channel 1 to scope channel 4; this helps model the delay that will be apparent in the plotted waveforms. The circuit also contains 50-ohm resistors to simulate the loading offered by the channel 1 input and the channel 4 input. (These resistors would probably be more appropriately represented in a test circuit for the DUT dut_8130.)

Setup specifics

Edit the td_meas setup (mdl8130) as described in the following input and output tables.

Table 113 Inputs

Input Name	Value / Description
time	This input is necessary to specify the time window for which the measured and simulated data will be acquired. It uses the Mode T. Naming it time is not necessary. The start and stop times are selected so that several complete waveforms will be plotted.

Table 113 Inputs

Input Name	Value / Description
ext_pulse	This input describes the pulse stimulus, for simulation purposes. For measurement, you should attempt to key in the same values on the front panel of the pulse generator being used. Note the following comments on some of the important fields. Mode: must be V + Node and - Node: points across which a simulated pulse is applied Unit: must be PULSE1, which corresponds to the output of the 8130. Type: must be PULSE or TDR. PULSE is used in this example. Pulsed Value: 4.0 was the value used to generate the measured data seen in the plot for this setup. Unless you have 20dB attenuators on the scope inputs (a suitable attenuator for 3.5mm connectors is part no. 33340C), this value should be adjusted below 320mv. Rise Time, Fall Time, Pulse Width: Set to 2u, 4u, and 40u for this example. Delay Time, Resistance: Set to 0 for this example. Period: Set to 60u for this example.

Table 114 Outputs

Output Name	Value / Description
wave1	This output will collect a waveform on the 1st input port of the scope. Note the use of CH1 to specify this. The Mode should be '. The simulated waveform is captured across the + and - Nodes shown. A similar wave4 output can be defined to collect a waveform on CH4 of the scope.

Table 114 Outputs

Output Name	Value / Description
period, pwidth, nwidth, risetime, falltime, swing	These outputs are only available for measurement (note the type M) because the oscilloscope computes it using special firmware algorithms. The Mode T is used to request these special Time-domain computations from the scope. By pressing the middle mouse button on the field Pulse Param, you can obtain help (in the Status panel) regarding the choices available from the scope.

Calibration

If you want IC-CAP to use your Channel Gain and Skew calibrations (performed via the front panel) follow these guidelines:

1. For a skew calibration, perform a dummy measurement, to get the time axis parameters downloaded.
2. Follow the instructions in the Front-Panel Reference for Gain and/or Skew calibration.
3. Continue with IC-CAP measurements.
4. If the time window is changed while using skew calibration, this procedure should be repeated.

The instrument should be powered-on for 15 to 30 minutes before attempting calibration.

Tips

- The open circuit voltage of the scope's own pulse generator is 400mV. See the Pulsed Value information for the TDR Example in Table 109 on page 985.
- The Offset and Range options available for each channel do not affect the range and resolution of measured waveforms. However, poor selections can cause errors in the T Mode measurements described previously.
- The Instrument Option ‘Averages’ should be used with caution when making certain T Mode measurements, such as Risetime. An averaged waveform will appear to exhibit a slower transition than any single instance of the same waveform. (Consult the Front-Panel Reference for your oscilloscope.)

In algebraic terms, the instrument returns Risetime(average(waveform)), and not average(Risetime(waveform)) when Averages >1 and a T-Mode output for Risetime is established.

Other instrument-computed pulse parameters are obtained the same way, though only the edge-speed computations suffer adverse effects.

Aligning Measured and Simulated Data

This example demonstrates aligning simulated and measured time-domain data when using a Pulse Generator.

The HP 8130 has a delay between its trigger output and its signal output. This delay induces a minor difficulty when attempting to align simulated and measured data, because simulators have no such delay. This delay has some dependency on pulse parameters, especially Period. This was accounted for during driver design by adding the 'Pulse Delay Offset' instrument option.

The value specified for 'Pulse Delay Offset' is added to the TDR or PULSE input's Delay value. Positive values will shift the waveform to the right, and negative values will shift the waveform to the left. This option enables you to align the simulated and measured waveforms. The option may need adjustment if the Period is changed. The default for this option is zero.

A fundamental problem with time-domain measurement is that the instruments do not have infinite speed, so you cannot measure everything you can simulate.

There are two situations when this is really important:

- The 54120 series cannot digitize any data until at least 16ns after a trigger edge is received. For this reason, IC-CAP imposes a lower bound on the T-mode Start time, to protect you from obtaining invalid data.
- The HP 8130 emits a trigger pulse approximately 18ns before its signal pulse. It was designed this way because oscilloscopes may need some 'setup' time to capture the first edge appearing on the pulsed signal line. In plots, this causes the measured waveform to shift to the right, relative to the simulated waveform.

To obtain good time-axis alignment between simulated and measured data, we recommend these steps:

- Increase the Delay in the PULSE input in the setup. This should shift the simulated waveform to the right.

- Decrease the HP 8130's ‘Pulse Delay Offset’ Instrument Option. This should shift the measured waveform to the left, inducing alignment.

By following the above steps, there should be no problem obtaining proper alignment between simulated and measured waveforms.

Note that if you try to set ‘Pulse Delay Offset’ to less than zero, you may get a measurement error message. To avoid such errors, first increase the Delay field in the PULSE or TDR type input. The instrument's ‘Pulse Delay Offset’ option plus the Delay in the PULSE input must add to greater than or equal to zero.

H
User C Functions

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You can write C routines that can be called from Programs or Macros. These routines can open, read, write, and close files. You can also specify any desired offset in the file, and display that position for reference. The location of these files is $ICCAP_ROOT/src.

IC-CAP imposes no limit on the number of files you can have open at one time. For limits of your operating system, refer to your operating system documentation.

The point-by-point assignment User C I/O capability increases IC-CAP's flexibility in accepting data sets from external sources. For additional information, refer to "Assignment" on page 704.

Tip:

- To view the arguments required by any given function from within the program, create a standalone transform and supply the desired function name in the Function field. IC-CAP will provide labeled fields indicating the arguments required by that function for use in a transform.

Example 1

This example shows how to read a data set from a file using the following three functions:

- USERC_open
- USERC_readnum
- USERC_close

Example 1, to be coded as a Transform Program from a Setup

```
! This Program reads a data set from a disk file 'datafile'.
! It is assumed that the file has scientific notation
! numbers, e.g., 15 or 15.0E3, separated by white space.  The
! white-space can be any amount of blanks, tabs,
! carriage-returns, or newlines (linefeeds).
fnum = USERC_open("datafile","r")
! open a file for reading
COMPLEX tmp_array[SIZE(vb)]
! array as big as data set 'vb'
i=0
WHILE i < SIZE(tmp_array)
  data_pt=USERC_readnum(fnum,0," %lf")
! fnum came from USERC_open.
! 0 indicates NOT an instrument.
! " %lf" (leading space intentional)
! is to scan for any amount of
! white-space (including none),
! followed by a long-float number,
! i.e. a double precision
! real number.
  PRINT data_pt
! To show each value as it is read.
  tmp_array[i] = data_pt
  i=i+1
END WHILE
status=USERC_close(fnum)
! close the open file.
RETURN tmp_array
! store data, for plotting, etc.
```

Example 2

This example causes the transform to read the specified file <datafile> and return the array contained therein, using the following function:

- USERC_read_reals

The floating point numbers in the file can be separated by various separators, including any mixture of newlines, tabs, and spaces, as well as comma (,) and semicolon (;) characters.

The USERC_read_reals function offers a simpler solution than Example 1. And it is possible to use the notation 'USERC_read_reals(<datafile>)' elsewhere in IC-CAP; for example, it can be used directly in a Plot definition.

Additional comments can be found in the source file $ICCAP_ROOT/src/userc_io.c. If you intend to modify the functions, or create new versions, you should save the original source file. For more information, review "Creating C Language Functions in IC-CAP" in the *User's Guide*.

Example 2, to be coded as a Transform Program from a Setup

```
return USERC_read_reals(<datafile>)
! read an array of reals from a file
```

Function Descriptions

USERC_open

This function opens a file for reading, writing or both. It returns one value: -1 or an integer file descriptor. The -1 value indicates an error. The integer file descriptor must be saved and supplied to a variety of other USERC functions.

USERC_open accepts two arguments:

- The first argument is the pathname of the desired file to open.
- The second argument is the access mode.

Listed below are some guidelines taken from the UNIX man page fopen(3S). For additional information, see that page.

r	read
w	write
a	append
+ mode	(update mode) if you must read and write the file, or you want to write to specific locations without losing previous data in the file.
r and r+	(read) modes will never create the file if it does not already exist. All four of the "w" and "a" (write and append) modes will create the file if is not there.
w and w+	Modes will truncate an existing file

Tips:

- Refer to "Hints for Reading/Writing Same File" on page 1009 for tips on reading from and writing to the same file.
- With instruments, it is highly advisable to use USERC_open once with mode "r" for reading, and once with mode "w" for writing. This avoids some problems in the standard I/O library that involve positioning in the I/O stream.

USERC_close

This function closes an open file. It returns a value indicating the status. If successful, it returns 0; otherwise it returns -1.

USERC_close accepts one argument:

- The file descriptor obtained from the call to USERC_open.

It performs an fclose(3). By default, the system will call fclose for all files opened by the User C I/O facility whenever the last Program or Macro terminates. It does this with userc_end_of_prog(), which is described in $ICCAP_ROOT/src/userc_io.c.

USERC_write

This function prints anything to an open file, in ASCII. It returns a value indicating the status. If successful, it returns 0; otherwise it returns -1.

USERC_write accepts three arguments:

- The first argument should be a file descriptor obtained from USERC_open.
- The second argument should be a flag (0 or 1) indicating whether the output file should be considered a device file, that is, an instrument. Use 0 unless you are reading from an instrument.
- The third argument should be a string, for example. VAL$(2), or VAL$(BF), or "TNOM="&VAL$(TNOM)&newline_string.

Tips:

- This function calls fflush(3) to ensure that a write-to-file or write-to-instrument is never delayed by the buffering present in the standard I/O facility.
- For information regarding instrument timeouts when writing, refer to “Hints for Timeouts” on page 1008.

USERC_readnum

This function reads one real number from a file, for example, 1.0E6. (See also USERC_readstr.) It returns one value: a real number read from a file or from an instrument. The returned value should be a valid real number if one exists; else the value is set to 9.99998E+37, for example, if EOF is encountered. (This mimics what the HP 54120 does when no valid data exists, but is a slightly different value.)

USERC_readnum accepts three arguments:

- The first argument should be a file descriptor obtained from USERC_open.
- The second argument should be a flag (0 or 1) indicating whether the input file should be considered a device file, that is, an instrument. Use 0 unless you are reading from an instrument.
- The third argument should be a scanf format string, for example, "%*5s%lf%*1[\n]", which means skip over a 5-character string, then get a double number, then read and skip a newline. (Consult man page scanf(3S).) The scanf format string provides some flexibility in terms of separating the number out from any surrounding text or mnemonics that are not of interest.

Tips:

- To avoid a potential core dump, %lf should be included only once, and any other "%" specifiers should have an asterisk (*) after them.
- If reading from an instrument that must communicate multiple data points in one read, it is necessary to create a modified version of this function to obtain those multiple data points.
- For information regarding instrument timeouts when reading, refer to “Hints for Timeouts” on page 1008.

USERC_readstr

This function reads a string from a file and places it in an IC-CAP variable you specify. (See also "USERC_readnum" on page 1004.) It returns a value indicating the status. If successful, it returns 0; otherwise it returns -1.

USERC_readstr accepts four arguments:

- The first argument should be a file descriptor obtained from USERC_open.
- The 2nd argument should be a flag (0 or 1) indicating whether the input file should be considered a device file, that is, an instrument. Use 0 unless you are reading from an instrument.
- The third argument should be a scanf format string, for example, %*5s%s%*1[\n]. This example means skip over a 5-character string, then get a string, then read and skip a newline. (Consult man page scanf(3S).) The scanf format string provides some flexibility in terms of separating the number out from any surrounding text or mnemonics that are not of interest.
- The fourth argument should be the name of an IC-CAP variable that receives its value from the string that is read.

Tips:

- To avoid a potential core dump, %s should be included only once, and any other "%" specifiers should have an asterisk (*) after them.
- For information regarding instrument timeouts when reading, refer to "Hints for Timeouts" on page 1008.

USERC_seek

This function goes to a particular byte offset in a file. (This function is basically an interface to fseek(3S)). It returns a value indicating the status. If successful, it returns 0; otherwise it returns -1.

USERC_seek accepts three arguments:

- The first argument should be a file descriptor obtained from USERC_open.
- The second argument should be an offset in bytes.
- The third argument should indicate the relative starting point for the offset. Use 0 if you want the seek offset to be relative to the beginning of the file, or 1 if the seek offset should be relative to the current position in the file.

Tips:

- Each line in an ASCII file uses 1 byte for a newline terminator.
- USERC_tell can be used to determine the current position, if you intend to seek elsewhere, and then return to the current position.
- It is neither useful nor advisable to use this function on device files, such as instruments or terminals.

USERC_tell

This function shows the current byte offset in a file. (This function is basically an interface to ftell(3S).) It returns a value indicating the status. If successful, it returns 0; otherwise it returns -1.

USERC_tell accepts one argument:

- The argument should be a file descriptor obtained from USERC_open.

USERC_read_reals

This function opens a file, reads an array of reals, closes the file, and returns an array. It returns -1 if the file could not be opened for reading, else 0.

USERC_read_reals accepts one argument:

- The argument should be the name of a file with real number data.

Invoking this function produces the following sequence of actions:

- Read real numbers from a file
- Return them as an array in iccap
- Open, read, and close the data file
- Close file in the event of user-requested interrupt (Ctrl-C)
- Print warning if unexpected number of points in file

Hints

Hints for Instruments

Instrument I/O is undertaken by opening a device file associated with the instrument. As described in the section USERC_open, instrument input and output is best accomplished by dedicating two separate file descriptors, one for reading, and one for writing. The USERC_open function can be called twice, as shown in the following example:

```
rdfile = USERC_open("/dev/hpib_721","r")
! for reading input
wrfile = USERC_open("/dev/hpib_721","w")
! for writing output
status=USERC_write(wrfile,1,"*IDN?")
! ask for ID of 54120
status=USERC_readstr(rdfile,1,"%s%*[\n]",readstr)
! read ID into readstr, and discard trailing newline
status=USERC_close(rdfile)
status=USERC_close(wrfile)
```

If instrument I/O is intended, you may want to review the documentation provided for the User C prober facility. This facility offers several GPIB routines that could be valuable, for example, serial polling.

Because of the need for instruments to sometimes communicate several data points at once (compared to retrieving data from a file, where you can obtain exactly as much data as desired, in as many reads as desired), it will probably be necessary for the read functions, USERC_readnum and USERC_readstr, to be extended and modified for use with some instruments. One possibility would be new User C functions dedicated to reading entire arrays out of particular instrument types.

Hints for Timeouts

By default, the routines for reading and writing do not employ a timeout. However, you can interrupt them using Ctrl-C. The UNIX library routine io_timeout_ctl can be used to associate a timeout with one of the file descriptors returned by USERC_open. This would require that one or more

of the above routines be modified, after which recompiling and linking are necessary. For details, refer to Creating C Language Functions in IC-CAP" in the *User's Guide*.

Hints for Reading / Writing Same File

If you need to read from and write to the same disk file, you should employ USERC_open once, using one of the following update modes "r+", "w+", or "a+." Then, you should adhere to the following guidelines (which are also described on the UNIX man page fopen(3S)):

- A write should not be immediately followed by a read without performing an intervening seek.
- A read should not be immediately followed by a write unless the read encountered end-of-file, or you perform an intervening seek.

Hints for Carriage Returns, Line Feeds, etc.

The functions for reading and writing (USERC_readnum, USERC_readstr, and USERC_write) can handle a limited set of unprintable characters. For example, an instrument can be sent a string with a trailing carriage return and line feed, as shown next.

```
status=USERC_write(wrfile,1,"*IDN?\r\n")
! \r and \n => CR and LF
```

If you want to collect a string from an instrument, and the instrument is going to attach a trailing carriage return and line feed, but you want to retrieve the whole string except for the terminating carriage return and line feed, follow the example shown next.

```
status=USERC_readstr(rdfile,1,"%[^\r\n]\r\n",readstr)
! note: the specifier %[^\r\n] collects
! all characters EXCEPT \r and \n
```

The set of characters that can be specified in this manner is the same as those accepted by the Send String command (Instrument Setup window). For details, refer to "Macro File Syntax Rules" on page 787.

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DIL-related Functions 1012
Other Functions 1013

The 'icedil' functions are used to control a raw GPIB device file from userc functions. These functions provide a thin layer on top of the HP DIL library to hide GPIB specific details, thus making it easier to use GPIB I/O as well as to port userc functions to non-HP machines. The source files are written in plain C and are provided with a Makefile.

There are two icedil files in *$ICCAP_ROOT/src*:

icedil.h	Contains low level I/O call prototypes
icedil.c	Includes actual codes for each ice_hpib_xxxx call

Most icedil functions are named after corresponding DIL functions and return the same values. However there are some functions that do not correspond to any DIL functions.

DIL-related Functions

The following functions perform the same task as their corresponding DIL functions. They are provided to facilitate porting to non-HP machines. For descriptions of these functions, refer to your GPIB documentation.

- ice_hpib_abort
- ice_hpib_bus_status
- ice_hpib_eoi_ctl
- ice_hpib_ren_ctl
- ice_hpib_send_cmnd
- ice_hpib_spoll
- ice_hpib_status_wait

The following functions also perform the same task as their corresponding DIL functions, however the corresponding DIL functions are named as io_xxxx instead of hpib_xxxx.

- ice_hpib_get_term_reason
- ice_hpib_eol_ctl
- ice_hpib_lock
- ice_hpib_unlock
- ice_hpib_timeout

Other Functions

The following functions are translated either to system calls or to a set of low level functions to make GPIB programming easier. The controller address on a GPIB is kept in a static array hidden in icedil.o so that users of this library do not need to remember it. However users can read this address at any time using ice_hpib_get_address().

ice_hpib_bus_init	This function takes an eid (entity id) and initializes the raw GPIB associated with this eid as follows: EOI Enable EOL No EOL character Timeout 2 sec Remote Line Asserted
ice_hpib_open	This function takes a device file name (full path name) and a flag (usually O_RDWR) to be passed to open() system call. It opens this device file and initializes it by calling ice_hpib_bus_init(). This function must be used prior to using a raw GPIB device file.
ice_hpib_read	This takes an eid, a pointer to a character buffer, the maximum number of bytes to read, and an addrs. It sets myself a listener and the addressed device a talker, then receives the response from that device.
ice_hpib_write	This function takes an eid, a pointer to a character buffer, the number of bytes to send, and addrs. It sets myself a talker and the addressed device a listener, then sends the specified characters to that device.
ice_hpib_close	This function takes an eid and closes the device file associated with this eid. This function is used to terminate communication with this device file.
ice_hpib_clear	This function takes an eid and a GPIB address. It sends a Selected Device Clear to the GPIB device specified by the addrs.
ice_hpib_get_address	This function takes an eid and returns my GPIB address on the device file associated with the eid. Usually this is 21. Note that currently no function is provided to change this controller address.

ice_hpib_listen	This function takes an eid and a GPIB address. It prepares the GPIB so that the device specified by addrs is a talker and myself is a listener. This function is called from ice_hpib_read().
ice_hpib_talk	This function takes an eid and a GPIB address. It prepares the GPIB so that the device specified by addrs is a listener and myself is a talker. This function is called from ice_hpib_write().
ice_hpib_wait	This takes one float and waits for the float second. This is implemented as a busy wait with the gettimeofday() system call.
ice_hpib_strpos	This takes two strings (string1, string2) and returns the position of the string2 in string1. This is similar to POS() function in HP BASIC.
ice_hpib_raw_read	This takes an eid, a pointer to a character buffer, and a length. This reads up to the length number of bytes from the device file specified by eid until it sees either an EOI or a terminal character. This function does not set up a talker/listener pair on the bus.
ice_hpib_raw_write	This takes an eid, a pointer to a character buffer, and a length. This writes out the length number of bytes from the buffer without setting up a talker/listener pair on the bus.
ice_hpib_check_eid	This is a "static" function visible only inside of icedil.c file. This function returns 0 if the given eid is out of the valid range and non-zero for a valid eid.

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